U. S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

# HYDROGRAPHIC MANUAL

K. T. ADAMS

SPECIAL PUBLICATION NO. 143
Revised (1942) Edition

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U. S. DEPARTMENT OF COMMERCE

JESSE H. JONES, *Secretary*

COAST AND GEODETIC SURVEY

LEO OTIS COLBERT, *Director*

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# HYDROGRAPHIC MANUAL

*by*

COMMANDER K. T. Adams
*U. S. Coast and Geodetic Survey*



UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON 1942

For sale by the Superintendent of Documents, U. S Government Printing Office, Washington 25, D. C. - - - Price $2.75

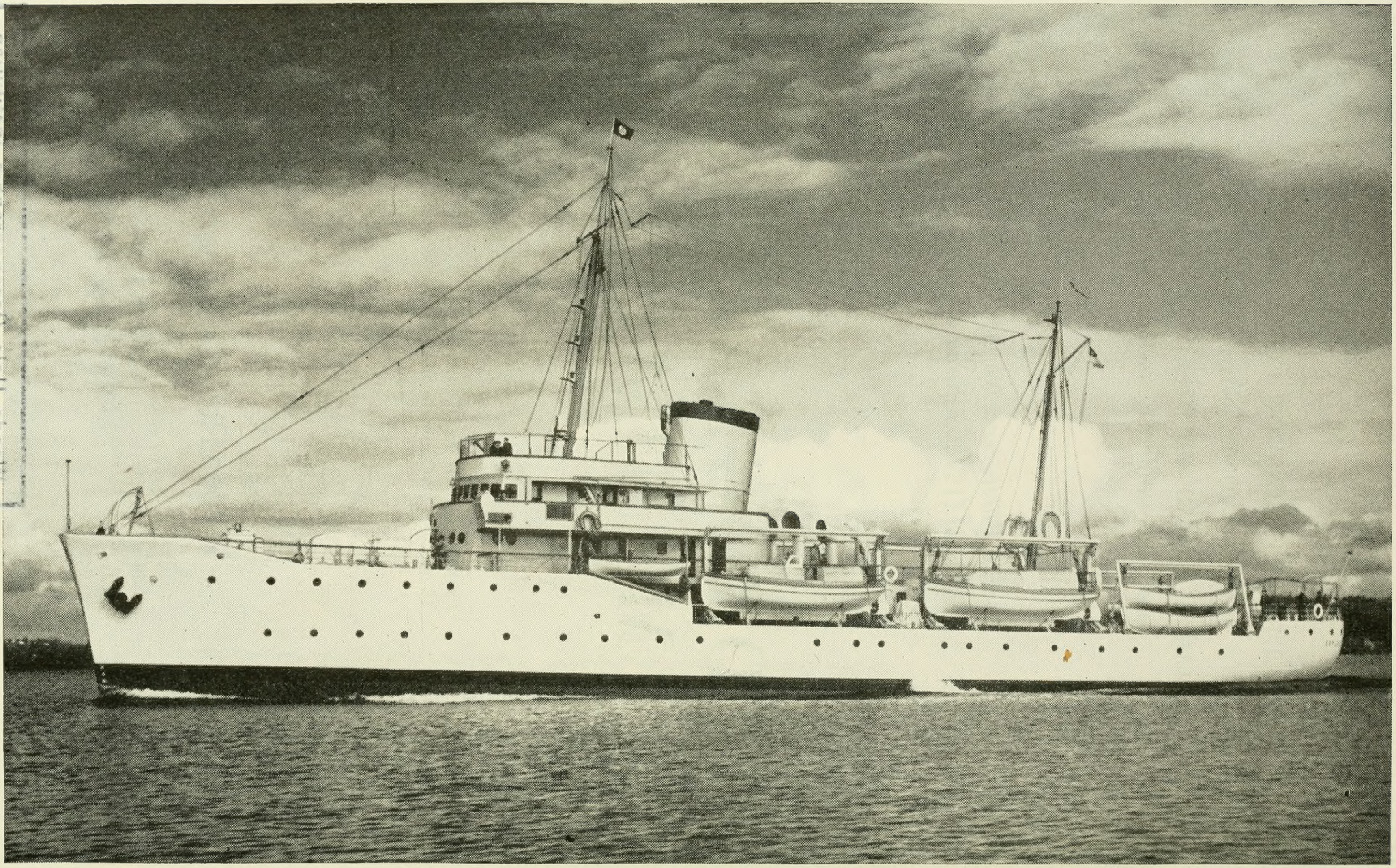

FIGURE 1.—Coast and Geodetic Survey ship *Explorer*. The *Explorer* is 198.7 feet long, 38 feet beam, and 15 feet draft. Her normal complement is 23 officers and 68 men; she has four 30-foot launches, four 24-foot whaleboats, and several smaller boats. She is equipped with the most modern survey equipment. One or two auxiliary vessels usually operate in conjunction with this ship. The *Explorer* is briefly described in 412.

Subject Head

7 3 2 6

Section

# PREFACE

Chapter

The Hydrographic Manual has been prepared and is issued to provide a textbook in which modern methods of hydrographic surveying and equipment are described. In it are stated the general requirements of the United States Coast and Geodetic Survey for the execution of hydrographic surveys. It is one of a series of manuals covering the various survey operations of the Bureau.

This Manual describes in detail for the first time instruments and methods used in echo sounding and Radio Acoustic Ranging. Many of the methods and details contained herein are based on the reports of officers and employees of the Bureau, too numerous for individual mention, who by their zeal and ingenuity in devising or developing new methods and equipment have contributed largely to the progress of hydrographic surveying during recent years. This is particularly true of the Radio Acoustic Ranging method of locating the positions of soundings, which has been brought to its present state of efficiency by this Bureau through the untiring efforts of personnel interested in attaining greater accuracy and reliability.

The subject matter in this Manual has been identified by a decimal numbering system and all referencing is by these numbers. The reader should understand the significance of these numbers. There are nine chapters, each of which is divided into not more than nine sections. Each section is subdivided into not more than nine subjects and each subject into not more than nine numbered headings. The first digit of a number identifies the chapter, the second digit the section, the third digit the subject, and the fourth the heading. For example **7326**, Verification of the Projection, is the sixth heading under the second subject in the third section of chapter 7, entitled "The Smooth Sheet."

This edition of the Hydrographic Manual has been prepared under the direction of Captain Gilbert T. Rude, Chief of the Division of Coastal Surveys. Much valuable assistance and advice have been received from officers and personnel both in the field and Office. Several officers contributed to the actual compilation of the text, but special credit is due to Commander Henry B. Campbell who wrote section **91**, Coast Pilot, and to Lieutenant Commander John C. Mathisson and Mr. Thomas J. Hickley, associate electrical engineer, who wrote most of chapter 5, Echo Sounding, and chapter 6, Radio Acoustic Ranging, and to Mr. Aaron L. Shalowitz, principal cartographic engineer, Division of Charts, for his collaboration in writing chapter 7, The Smooth Sheet, and for his assistance in reviewing and editing the entire manuscript.

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Department of Commerce,
United States Coast and Geodetic Survey,
*Washington, D. C.*

The requirements for hydrographic surveying in this edition of the Hydrographic Manual supersede all previous manuals, instructions, and circulars on the pertinent subjects and, together with the Regulations for the Government of the United States Coast and Geodetic Survey, shall be complied with in executing all hydrographic surveys unless divergence therefrom is authorized in the instructions issued for each project.

Leo Otis Colbert, *Director*

# *Hydrographic Manual*

## CHAPTER 1. PRELIMINARY

### 11. GENERAL STATEMENT

Every important maritime nation surveys its coasts and territorial waters and publishes nautical charts of the world sea routes. Nothing has been of more importance in the establishment and development of a merchant marine than the production of nautical charts, which in turn must be based on accurate hydrographic surveys. As long as sea-borne commerce continues, hydrographic surveys will be required.

Few of the coasts of the world have been adequately charted and the depths in most of the water areas are still only imperfectly known. Furthermore, even where adequate charts have once been made, man and nature are constantly changing the depths of the water, the coastline, and the adjacent structures, so that frequent revision surveys are required. Moreover, the increased draft of vessels and the importance of maintaining schedules call for more critical surveys, and render charts and surveys obsolete which once were considered adequate.

Formerly, no extensive survey of the bottom configuration was made except in the lesser depths near the shore, in channels, and in the vicinity of shoals. Today, a detailed hydrographic survey is required regardless of the depth, for the bottom configuration where accurately indicated on a chart may provide a simple means of locating a vessel underway from a series of soundings taken with an echo-sounding instrument. The same instrument allows the detailed surveys to be made expeditiously, it being no longer necessary to stop the ship to obtain the deeper soundings.

### 111. Introduction

The first hydrographic information available for the use of mariners was in the form of written descriptions of the coasts along which they sailed. These were crude beginnings of what we now know as Sailing Directions, or Coast Pilots. At first, they probably consisted of the merest details of headlands. As the early seafarers ventured farther from home, it was found desirable also to preserve information concerning the channels and harbors, and the dangers to be avoided along such routes.

These descriptions were primarily for the safety of the mariner and were first prepared by the mariners themselves, who passed from one to another the details of the routes to be followed and the places visited. They may have been accompanied by crude sketches and if so, these were the first maps prepared especially for the use of seafarers. That they were of utilitarian value only, may account for the fact that they were not permanently preserved.

The first marine charts of which there is actual record are those constructed by Marinus of Tyre during the second century. He was followed by the Egyptian Ptolemy who made use of his charts. Ptolemy published a list of places to which

he tried to assign proper geographic positions and included in his work the mathematical principles for the scientific construction of maps. He refers to maps which are supposed to have been a part of his original work. At any rate maps were delineated from his data a century or more later.

During the next thousand years there was little progress in cartographic knowledge. In fact there was retrogression, for the knowledge that the earth was a globe was largely lost sight of and there was a return to the popular belief in its flatness. The Crusades, the development of commerce by the cities of Italy, and a knowledge of the properties of the magnetic needle, all combined to revive an interest in cartography and led to the development of the Portolan Charts in about the fourteenth century.

The Portolan Charts were intended primarily for the use of mariners, and Italy and Catalonia, the two foremost maritime countries of the age, were principally responsible for their development. They were compiled from the exploratory surveys of the period but were most notable for the loxodromic, or rhumb, lines with which they were covered. No projection was used in the construction of these charts but they were generally drawn with considerable care. An attempt was evidently made to represent the coasts of the various countries in mutual relationship to one another based on the distances and courses actually run between points. The oldest Portolan Chart now extant, which can be accurately dated, is credited to Petrus Vesconte in 1311.

The era of exploration and discovery which immediately preceded and followed the discovery of America by Columbus, and the invention of printing in the fifteenth century, contributed to the renaissance of map and chart making in the fifteenth and sixteenth centuries. It was during this era that Mercator published his well-known world map in 1569, on the projection which bears his name. His was the first real attempt to base a map on a mathematical projection. The meridians and parallels are represented by straight parallel lines intersecting one another at right angles. The meridians being equally spaced on this form of projection, the intervals between the parallels of latitude are increased proportionally to compensate for the actual convergence of the meridians on the earth. This projection is now almost universally used for the construction of nautical charts, since it facilitates rhumb-line navigation. Mercator was certainly the foremost cartographer of his generation and, in the opinion of some, his projection is the greatest contribution of all time to the modern nautical chart.

## 112. The Nautical Chart

A nautical chart is a reproduction, on a reduced scale, of some portion of the navigable part of the earth's surface. It is a map constructed to serve the needs of the mariner. It usually includes the adjacent land area, but its principal function is to show the depths of the water and the menaces to navigation which are to be avoided. It should emphasize the shore features of most use to the mariner and must include all artificial aids to navigation.

The earth's surface is spheroidal and any portion of it, no matter how small, is a convex surface. For convenience in construction and use, the portion included on a chart must be represented on a plane surface. Since it is impossible, even by curving it, to make a flat piece of paper coincide with the surface of a sphere, it is obvious that a strictly accurate representation of a portion of the earth's surface is not possible on a piece of paper. Some distortion is inevitable, but the smaller the area embraced, the less appreciable will be the errors of representation, until in harbor charts and others of large scale and small extent these errors are scarcely measurable.

A modern nautical chart, compiled from an accurate survey, is necessarily based geographically on some definite form of projection. Numerous types of projections have been devised, each with a particular purpose in view, but the two which have properties peculiarly useful in navigation are the Mercator and the gnomonic.

### *1121. The Mercator Projection*

The Mercator projection was invented by Gerhard Krämer (Mercator) in 1569, and practically all modern small-scale nautical charts and many large-scale ones are constructed on it. For nautical charts, then, except in high latitudes, the Mercator projection has attained an importance far above all others. It is a type of projection, derived by mathematical analysis, in which the meridians are straight equally spaced parallel lines, and the parallels are straight parallel lines at right angles to them but whose distances apart for a sphere increase at a rate varying with the secant of the latitude.

The projection has a number of advantages, among which are simplicity of construction, convenience in plotting positions from the border divisions, and the fact that on it alone a course can be laid off from any meridian or compass rose within its borders. Its principal advantage, however, and the one responsible for its world-wide use for nautical charts, is that any straight line drawn on it in any direction is a rhumb line, or loxodromic curve. The track of a ship on a constant course is a straight line on the projection and it will, theoretically at least, pass all features along that line exactly as they are charted. This is a great advantage in extensive coastal navigation, in that the straight line representing a constant course made good will indicate at once the distance abeam dangers will be passed.

Disadvantages of the Mercator projection are that it exaggerates areas appreciably—seriously where an extensive north and south area is included—and that the scale is constantly changing with latitude, so that a graphic scale cannot be used on the smaller-scale charts, making it necessary to measure distances along the border divisions for the latitudes in which the distance lies.

Most of the nautical charts published by the Coast and Geodetic Survey and all newly constructed charts are on the Mercator projection. The most recent and best tables, and those used by the Coast and Geodetic Survey, for the construction of Mercator projections are those issued by the International Hydrographic Bureau at Monaco, 1928.

Much information about the Mercator projection and its construction is contained in The American Practical Navigator (Bowditch), pages 38 to 40, and in Coast and Geodetic Survey Special Publication No. 68, Elements of Map Projection. The latter publication also contains tables to three decimal places, which accuracy is sufficient for all practical purposes.

### *1122. The Gnomonic Projection*

The gnomonic projection is a perspective projection upon a tangent plane, the projecting lines radiating from the center of the sphere. Obviously only a limited portion of the globe can be represented on this projection.

Its one special property of value to seamen is that any line of sight, or part of a great circle, is represented by a straight line on the projection. Thus all plotted bearings, either visual or radio, are straight lines, and by it a mariner can readily determine the

shortest route between any two points. In almost every other respect the projection is faulty. The scale is not constant, but increases from its constructional center outward, so that distances, areas, and shapes are very much distorted near its boundaries. Azimuths, except at the point of tangency, can be plotted only by means of a specially constructed compass rose.

Gnomonic charts are used principally in connection with great-circle sailing for finding the shortest possible track line between any two points and the course at any point along the track. Polar regions, where the Mercator projection is nearly useless, are also charted on this projection.

The projection and its mathematical theory are treated more fully in Special Publication No. 68.

### *1123. The Design of a Nautical Chart*

A nautical chart is designed solely with reference to the needs of navigation in a certain area. But even in one area there is a variety of needs; a transoceanic liner entering a port and restricted to the main channels does not need the same information on a chart as a tugboat which may not follow the regular channels and may be required to venture into unfamiliar places. A variety of scales of charts to meet various needs is required.

The nautical charts published by the Coast and Geodetic Survey are constructed on certain convenient standard scales, which are almost invariably multiples of the proportion 1:10,000. The standard scale of a Mercator chart generally applies to its middle latitude. For convenience in navigating on adjacent charts, some are grouped, and the standard scale applies to an appropriate latitude of the series; thus the scale of adjacent charts is the same in the overlapping area, but the scale at the middle latitude of each chart of the series may differ from the standard.

The limits of a nautical chart must be decided by the needs of navigation. Each must include near its limits suitable features for use as points of departure, and adjacent charts must overlap so that they include a common prominent feature. Because of these requirements it is customary to plan charts in a series, even though there is no immediate prospect of needing more than one or two of the series.

### *1124. Compilation of Charts*

Nautical charts are *compiled* from the field surveys of the Bureau and from miscellaneous data from various sources. It is extremely rare that a hydrographic survey is directly reproduced as a nautical chart, even at a reduced scale. Compilation is a process of evaluation of the available data, from which selection is made. Those features that are of little interest to the mariner are generalized or omitted altogether if they interfere with, or obscure, data of navigational value. By contrast, those features of greatest navigational importance are accentuated so they will not be overlooked.

Some chart users erroneously believe that a multitude of soundings on a chart is evidence that the region has been thoroughly and adequately surveyed. Of course, if only a few soundings were taken, only a few can be charted and the reconnaissance nature of the survey is clearly indicated by their arrangement on the chart. But, if there is a sufficient reduction from the scale of the survey to the scale of the chart, the area may appear to be well covered and the mariner is lulled into the belief that the area has been well surveyed and that he may navigate it in safety.

### *1125. The Datums of a Nautical Chart*

A nautical chart may be said to have two kinds of datums; vertical datums to which the depths and elevations are referred, and a horizontal datum to which features are referred by latitude and longitude.

The sounding datum, or the chart datum as it is sometimes called, is the plane of reference for the charted soundings; it is a tidal plane. The sounding datum is noted prominently in the title of each chart published by the Coast and Geodetic Survey; with minor exceptions, all depths on charts in the Atlantic Ocean are referred to mean low water (MLW) and those in the Pacific Ocean to mean lower low water (MLLW). (See also **2172**.)

The vertical datum for elevations, with minor exceptions, is mean high water (MHW) for all nautical charts of the Coast and Geodetic Survey (see **2173**).

The geographic datum, also called horizontal or geodetic datum, is the adopted position in latitude and longitude of a single point to which the charted features of a vast region are referred. Charts of waters bordering the United States are either on the North American datum or the North American datum of 1927; other charts are on various other datums, not connected with the continental triangulation. (See also **2171**.) Most charts of the Coast and Geodetic Survey do not indicate the datums they are on, but the legend "N.A. 1927" in the upper right-hand corner of the border of any chart, signifies that it is on the North American datum of 1927.

### *1126. Chart Accuracy*

The most important criteria by which the value of a nautical chart may be judged are its accuracy, adequacy, and clarity. A lack of any one of these may result in a marine disaster with consequent loss of life and property. Except for blunders in compilation, accuracy depends directly on the quality of the field surveys; the hydrographer and the cartographer are equally responsible for the adequacy, but the cartographer alone can embody clarity in a chart.

The nautical charts of the Coast and Geodetic Survey are noted for a clarity of which the cartographers and lithographers may well be proud, a quality toward which the Bureau has ever striven. And where the charts are based on modern surveys, their accuracy and adequacy are second to none.

The accuracy of a nautical chart is dependent on the accuracy and adequacy of the hydrographic surveys from which it is compiled; it cannot be more accurate. In general, it may be said that the date of a survey is an indication of its thoroughness and accuracy. A century ago there were such vast unsurveyed areas that the hydrographer was sometimes obliged to subordinate completeness and accuracy to speed, for even an inadequate chart is better than none at all. Since that time, decade by decade, standards have become stricter, and new methods and instrumental equipment have been devised and the former ones developed to greater perfection.

The scales of most hydrographic surveys are at least twice, and often several times, as large as the publication scales of the charts on which the information appears. The effect of this reduction in scale is to reduce the errors of plotting to an amount which, for all practical purposes, is not measurable at the chart scale.

### *1127. Dates on Charts*

The dates of the surveys from which a chart has been compiled are an important indication of the present trustworthiness of a chart, and this is especially so in a change-

able area. In the legend of Coast and Geodetic Survey charts under the heading "Authorities" will be found information of value relative to the dates of surveys. It should be noted that limits of surveys do not necessarily correspond with chart limits, and on small-scale charts, especially, the results of many surveys of various areas and dates may be embodied.

In addition to the dates given in the authorities note, there are three important publication dates on every chart issued, whose significance should be understood. These are termed *edition date*, *print date*, and *hand-correction date*.

The *edition date* appears in the publication note in the center of the lower margin of the chart. It is changed when a new edition is issued. A new edition is issued whenever corrections to the chart are of such extent and importance as to make all previous copies of the chart obsolete. The date does not necessarily indicate that the chart has been reconstructed, nor does it necessarily have any reference to the dates of the surveys.

The *print date* is the date, or the farthest to the right of a series of dates, appearing in the lower left-hand margin of the chart. The printing plates are corrected for all essential applicable information received prior to this date.

The *hand-correction date*, or date of issue, is impressed by rubber stamp in the lower right-hand margin of the chart near the printed note which reads "Lights, beacons, buoys, and dangers corrected for information received to date of issue." All changes in aids to navigation, newly discovered dangers, and other important data which are published in the Notices to Mariners subsequent to the print date are added by hand before issue.

## 113. The Hydrographic Survey

The principal object of all hydrographic surveying is to secure information concerning the water areas and the adjacent coasts for the compilation of nautical charts and Coast Pilots and for their correction.

### *1131. Combined Operations*

Hydrography is that branch of applied science which deals with the measurement and description of the physical features of the navigable portion of the earth's surface and adjoining coastal areas, with special reference to their use for the purpose of navigation. As such, it embraces a great variety of activities including: Astronomic observations, triangulation, and topographic surveys of the coasts; the observation and study of tides and currents; magnetic surveys; oceanography; the measurement of the depths of navigable waters; and the collection of various kinds of data needed in compiling and correcting nautical charts and Coast Pilots.

In a broad view, all of the above activities are included in hydrographic surveying, and a hydrographer will eventually be called on to perform each of them. In the Coast and Geodetic Survey many of these operations at times are conducted by separate parties, each organized and instructed especially for one specific duty, and because of this not all of the operations are considered as being included in hydrographic surveying.

In the Coast and Geodetic Survey the combined activities of a hydrographic party are termed *combined operations*, and a survey party whose principal work is *sounding* is said to be engaged on combined operations when its duties include other activities such as triangulation, topographic surveying, tide and current observations, and magnetic observations.

### *1132. Hydrographic Surveying*

As used in the Coast and Geodetic Survey, hydrographic surveying is one phase of combined operations and in this limited sense may be said to consist of three essential operations—sounding; location of soundings, and aids and menaces to navigation; and records:

(*a*) Depth measurements, usually called *soundings*, are made throughout the area being surveyed. This includes the determination of the nature of the bottom at selected intervals, and the measurements of some of the physical characteristics of sea water, such as water temperatures and salinities at various depths. Data may be collected for oceanographic research, such as specimens of bottom material and water samples.

(*b*) The positions of the soundings are determined by reference to control stations; numerous features, such as rocks, reefs, wrecks, and aids to navigation, are located and examined so that they may be charted for the guidance of navigators.

(*c*) All data are recorded and plotted to provide permanent records of all the information obtained during the survey and to serve as a basis for the construction of nautical charts and the compilation of Coast Pilots.

### *1133. Survey Projection and Scale*

Although most nautical charts are constructed on the Mercator projection, all original field surveys are plotted on the polyconic projection which is especially useful for this purpose (see **7321**).

The scales of the surveys are chosen with respect to the amount of detail in the area and are usually at least twice as large as that of the largest-scale chart to be published of the area. The scales are almost invariably multiples of the proportion 1:10,000. (See **123**.)

### *1134. By-product Value of Surveys*

In addition to their use in chart compilation, hydrographic surveys and other combined operations have an important by-product value. For many parts of the coast the topographic surveys are on a larger scale than are available elsewhere, and for some areas, especially outside the continental limits of the United States, they are the only topographic surveys existent. The results of the surveys are valuable for military defense, for planning harbor improvements, for the study of physical hydrography, beach erosion and other shoreline changes, and for oceanographic studies.

For much of the coastal area the early topographic surveys of the Bureau are the earliest authentic records of shoreline conditions and the detailed topography of the adjacent terrain. These and the periodic revision surveys of the constantly changing shoreline have a historic value, in addition to their value in land disputes.

The periodic hydrographic and topographic surveys are of great and increasing importance in the study of shoreline changes. The history of beach evolution during the past century can often be deduced from the records of the Bureau, with the result that the engineer can frequently determine the character of the forces which he seeks to control.

Students of the earth sciences have been handicapped in the past by their inability to investigate the vast unknown areas beneath the ocean surface. Except for the fringe along the coasts, soundings, even where taken, were so widely spaced and so inaccurately controlled in position as to give little basis for scientific conclusions. Gradually, with the perfection of echo sounding and more accurate methods of control, the submarine relief is being revealed, particularly that of the submerged continental margins. It is now possible not only to discover and chart the submarine features

but to survey even the precise details of form. In recent years submarine valleys along the continental slopes which were only partly known or suspected have been disclosed in surprising detail.

The hydrographic surveys have an extremely interesting and important significance for the geomorphologist; the submerged portions of the continental masses are being slowly revealed, and a better understanding of that part of earth history hidden beneath the sea is in prospect.

### 114. The Hydrographic Manual

This Manual is one of a series published by the Coast and Geodetic Survey to describe the methods and equipment and to state the general requirements for the various survey operations. As explained in **1132**, hydrographic surveying is considered to be only one phase of combined operations, for each phase of which there is a separate manual.

To avoid duplication, this Manual treats principally of the operation of sounding and of the details of hydrographic surveying after a topographic survey has usually been made and is available. It does include some important phases of other operations, particularly as applicable to hydrographic surveying, and supplements other manuals where the requirements have been changed.

For combined operations each hydrographic survey party needs continually at hand the following manuals, and frequently has use for many of the publications of the Bureau listed in **952**:

*Special publications*

No. 118. Construction and Operation of the Wire Drag and Sweep.
No. 144. Topographic Manual.
No. 145. Manual of Second- and Third-Order Triangulation and Traverse.
No. 196. Manual of Tide Observations.
No. 215. Manual of Current Observations.
*Serial* No. 166. Directions for Magnetic Measurements.

It should be noted that in this Manual the expression "hydrographic surveying" is almost always used in its limited sense, to refer to operations described in **1132**, although occasionally it may be used in the broad sense to include combined operations. Likewise, the term "hydrographer," as used, almost invariably refers to the officer in immediate charge of the hydrographic survey unit. For a survey ship, the hydrographer is, of course, the Commanding Officer; but for smaller units, the officer responsible for the daily operations of the unit, even though only temporarily assigned to such duty, is the hydrographer.

## 12. PROJECT

The field operations of a hydrographic survey in a specified area are considered a project, and to each project is assigned a number such as CS–253, the letters being the abbreviation for Coastal Surveys. Former numbers of the series were preceded by the initials HT–, which stood for Hydrography and Topography.

Each project is considered a "project of combined operations," since contemporary surveys of other types are usually required in connection with the hydrographic surveys in any area.

A project may consist of two or more minor surveys of a similar type in nearby areas even though the areas are not adjoining. The size of any one project is such

that it usually takes one survey party at least one season and perhaps several consecutive seasons to finish it.

### 121. PROJECT INSTRUCTIONS

Instructions, known as *project instructions*, are written for each numbered project to supplement the published manuals. The details of the instructions vary from specific to general, depending on the locality, whether there have been prior surveys by this Bureau in the area, and whether these were of a reconnaissance nature or were adequate at the time they were made. The instructions define the limits of the project area and indicate specifically what operations are to be performed, by what methods, and to what degree of accuracy. Frequently the purpose of the project is mentioned.

A copy of a chart of the area on an appropriate scale is usually furnished with the instructions, on which the limits of the project and the limits of all applicable prior hydrographic and topographic surveys within the area are indicated. The Chief of Party is furnished, without request, with copies of all existing data which are believed to be required for the operations. He should examine these thoroughly, on receipt, in connection with the instructions, to assure himself that all the necessary data have been included. If omissions are discovered or the data forwarded are considered insufficient, he should request from the Washington Office any additional data required.

Occasionally it becomes necessary to issue supplemental instructions to modify or supplement the original instructions, as where the progress of the survey discloses additional facts regarding the characteristics of the area. In all correspondence, all Descriptive Reports, season's reports, and special reports, which refer to the operations of the project, reference shall be made to the project number, followed, in parentheses, by the year in which the instructions were issued, as for example, CS–251(1939). If supplemental instructions have been issued, reference to these shall also be made when they are applicable.

The Chief of Party shall acknowledge the receipt of all project instructions and supplemental instructions. He is required to make a careful study of them as soon as the instructions and the accompanying data are received. He should report to the Washington Office immediately any revisions of the requirements which he recommends, any parts of the instructions which are not clearly understood, or any subjects relative to the project about which he desires more complete or additional information. The Chief of Party is urged, if the progress of the operations discloses the need therefor, to make specific recommendations for amendments to the original instructions or recommendations for the requirements of succeeding seasons' operations in the same or adjoining areas.

Ordinarily the project instructions will be divided into and treat of the following subjects: *General*, *control*, *topography*, *hydrography*, *tides*, and *miscellaneous*. Occasionally additional subjects are included, among which may be *magnetic* and *current observations*.

#### *1211. General Instructions*

In the general part of the project instructions the limits of the areas which are to be surveyed are specified, the offshore limits sometimes being defined by depths. The part of the area in which operations are to be begun is specified and the desired direction of progress. When two or more Chiefs of Party are assigned to operate in the same area on the same project, their respective operations and the division of authority are defined.

### *1212. Instructions for Geodetic Control*

Copies of progress sketches of all previous triangulation within the area will ordinarily be forwarded with the project instructions, as well as copies of all geodetic positions and descriptions of stations which the Chief of Party is likely to need to carry out his instructions. The project instructions will ordinarily state whether new triangulation is necessary, and if so, the requirements as to order of accuracy. If arcs of new triangulation are contemplated, the junction to be made with previous triangulation will be specified.

The instructions will often require that a search be made for, or that descriptions be written for, specific stations concerning which there is a known deficiency in the records at the Washington Office. Where geodetic control of other organizations is known to exist within the area, specific instructions for a connection thereto are generally included. Where there are objects of particular landmark value or important stations whose geodetic positions are known to be desired, the instructions will specify that these be located.

Unless otherwise specified by the project instructions, the principal geodetic control for all coastal hydrographic projects shall consist of stations located by second-order triangulation at intervals of about 5 miles along the coast, supplemented by intermediate stations located with third-order accuracy at intervals of about 2 miles along the coast. If the character of the terrain makes triangulation impracticable, the principal geodetic control of hydrographic projects may consist of second-order traverse with stations established at intervals of 2 miles along the coast.

All geodetic control shall consist of recoverable stations permanently marked by standard station marks, and natural objects which are recoverable without special marking. All geodetic control shall be established in accordance with the specifications and instructions contained in Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse, except as amended by section **22** of this Manual and by the project instructions.

### *1213. Instructions for Topography*

The project instructions will ordinarily specify to what extent topographic surveys are to be made, whether air photographic surveys of the area are anticipated in the near future, and whether the survey is to consist of a graphic control survey merely for the location of the hydrographic signals, a complete planetable survey of the shoreline and adjacent topographic features, or a revision survey of the shoreline and a verification of the other details from former topographic surveys of the area.

The scales of the topographic surveys are usually specified, even though they are ordinarily dictated by the scales of the inshore hydrographic surveys of the respective areas. A Chief of Party has the authority to make the topographic survey of any important part of the area at a larger scale than specified if, in his opinion, the larger scale is needed to provide for an adequate and fully developed hydrographic survey of the area.

The project instructions will generally specify where junctions are to be made with prior surveys and what steps are to be taken, if a check is not obtained at the junctions.

Photographic copies of prior topographic surveys which may be needed by the Chief of Party are furnished with the instructions. Blue-line prints of planimetric maps, if available, will ordinarily be furnished for possible revision of the shoreline and adjacent topographic detail.

All planetable topographic surveys shall be made according to the requirements and instructions contained in Special Publication No. 144, Topographic Manual, except as amended by section **23** of this Manual and by the project instructions. They shall always be made on aluminum-mounted sheets unless otherwise specified.

### *1214. Instructions for Hydrography*

The project instructions will ordinarily specify:

(*a*) The limits of the area to be surveyed, the junctions to be made with prior surveys, and the overlap required if a satisfactory check is not obtained at the junctions.

(*b*) The scales of the hydrographic surveys in different parts of the area. For coastal surveys the offshore limit of each scale is often defined by the depth of the water. Sometimes only the basic scale for the inshore hydrographic surveys is specified and the Chief of Party will be expected to select the appropriate offshore scales for an adequate systematic survey and development of the area, taking into consideration the available control. The Chief of Party is always authorized to use larger scales for any small parts of the area for which he deems it essential, as for example, important small harbors and anchorages.

(*c*) The maximum spacing between sounding lines for different parts of the area, sometimes only in a general way. The limits of the zones may be defined by distances offshore or by depths. It is to be noted that these are maximum spacings and the hydrographer is expected to reduce them if, in his opinion, this is necessary for an adequate development of any part of the area.

(*d*) The desirable direction or azimuth of the principal system of sounding lines to be run in the area, although the hydrographer should use his judgment regarding this, in order that the area may be most adequately and economically surveyed.

(*e*) The percentage of crosslines to be run, if any, as a check on the accuracy and adequacy of the survey.

(*f*) The depth curves which are to be drawn on the boat sheet, to aid in determining whether the area has been adequately surveyed and whether all indications of shoals and dangers have been investigated.

(*g*) That all critical depths and dangers to navigation on existing charts be proved or disproved. Reported shoals that require investigation may be individually mentioned.

(*h*) That certain areas which are periodically surveyed or have recently been surveyed by another agency be omitted, if such survey appears adequate and a satisfactory check of the depths can be obtained at the junctions.

(*i*) Any special development which may be required to delineate certain submarine features more completely than is otherwise specified for such depths.

(*j*) The interval between recorded soundings when the depths are to be read visually from an echo-sounding instrument. In the absence of such instructions at least as many soundings must be recorded as are ordinarily inked on the smooth sheet (see **7724**).

(*k*) The number of R.A.R. (Radio Acoustic Ranging) returns considered adequate to fix a position, where this method of control is used.

(*l*) The required frequency of bottom characteristics.

Photographic copies of all prior hydrographic surveys with which junctions are required are furnished with the instructions, as well as photographic copies of the most recent hydrographic surveys of the entire area, if the latter are believed to be of value to the hydrographer.

### *1215. Instructions for Tide Stations*

For the vertical control of the hydrographic surveys a knowledge of the height of the tide above the sounding datum is necessary at all times during hydrographic surveys. For this reason tide observations must be made at selected places within the project area, both for use in reducing soundings to the sounding datum, and for use in deriving data for the prediction of tides.

The project instructions will ordinarily specify what tide station is to be used as a standard for the project and where it is located if an existing station can be used, or where it is to be located if it is to be established by the survey party. An inspection of and a report on an existing standard gage may be required.

Supplemental tide stations are generally required and the instructions will specify how many of these are necessary and the desired locations. The minimum length of time each supplemental tide station is to be maintained will be stated. A Chief of Party is authorized to depart from the specified locations if, on examination, they appear impracticable.

Copies of the descriptions of previous tide stations in the area, with the elevations of the bench marks and the heights of the datum planes at each, will be furnished.

After the receipt at the Washington Office of the records of the establishment of a new station, including the level records and at least 2 weeks of satisfactory tide observations, a preliminary plane of reference can usually be derived for use in the determination of the tide reductions to be applied to the soundings. This plane of reference will be furnished to the survey party on request, but the request should be deferred until the datum is actually needed.

All tide stations shall be established in accordance with the instructions contained in **143** and in Special Publication No. 196, Manual of Tide Observations (revised 1941 edition), except as amended by the project instructions.

### *1216. Shore Magnetic Observations*

The project instructions may require magnetic observations at certain existing stations or at new stations to be established within the project area. The Washington Office will either specify a standard station at which the instrument used for the magnetic observations shall be standardized at the beginning and end of the season, or issue instructions to return the instrument to the Office for standardization.

In the absence of any specific instructions, magnetic observations shall be made with the compass declinometer, or equivalent instrument, at intervals of not less than 10 miles along the coast in areas where no magnetic anomalies are found, and at lesser intervals in magnetically disturbed areas. Where a magnetic anomaly of more than 2° is discovered, a sufficient number of additional observations shall be made in the area to delineate the extent of the disturbance.

The magnetic observations should be made at, or in the immediate vicinity of, a triangulation station, if possible. If the observations are not made at a triangulation station, sufficient data must be given to determine the approximate position of the magnetic station. An azimuth determined to the nearest minute is required at every magnetic station. If one is already available, definite information should be given so that it can be determined from data in the records at the Washington Office or from the records of the current field season. If an azimuth is not available, one must be observed to a natural object or a nearby recoverable station whose position is known. Three-point fixes should not be used for determining the azimuth, if other methods are available. If used, the stations must be positively identified, and the fix must be strong.

All magnetic observations shall be made in accordance with the instructions contained in Serial No. 166, Directions for Magnetic Measurements, *except* that, if the observations are made with a transit magnetometer, the special instructions which

have been prepared by the Washington Office for the use of this instrument shall be followed.

### *1217. Current Observations*

Where current observations are to be made, the project instructions will specify: (*a*) Where they are to be made; (*b*) the period of continuous observations required at each station; and (*c*) the instrument to be used in obtaining the data.

Current observations shall be made in accordance with the instructions contained in Special Publication No. 215, Manual of Current Observations, except as amended by the project instructions.

### *1218. Miscellaneous Instructions*

Under a miscellaneous heading the project instructions will specify other details of the operations. Among these are the scales to be used for the monthly and season's progress sketches. On the monthly progress sketch the Chief of Party is required to include the limits of the topographic and hydrographic sheets as these are determined during the field season. The standard size of the annual progress sketch is specified. If coast pilot notes are known to be required for the revision of or to supplement the Coast Pilot of the area, this will be stated. The instructions may specify that special reports be made regarding the use of certain new instruments or methods concerning which information is desired. The instructions may require that a report of dangers to navigation discovered be made elsewhere than to the Washington Office (see **8522**). Consultation with officials of certain organizations may be required.

## 122. Offshore Limits

The use of echo-sounding instruments now permits the extension of hydrographic surveys far beyond the limits formerly considered practicable. Commercial and naval vessels equipped with some of these instruments are now able to obtain soundings at will in the greatest depths of the oceans, with the result that they are virtually always "on soundings." Unless otherwise specified in the project instructions, hydrographic surveys should be extended as far seaward as it is practicable to control adequately the positions of the soundings.

Modern hydrographic surveys have disclosed numerous offshore submarine features, which are of incalculable value on the published charts for use as landmarks, from which vessels with echo-sounding instruments navigating these areas may determine their approximate positions when approaching a coast. On the continental slopes of the Atlantic and Gulf Coasts of the United States many submarine valleys have been discovered in recent years. On the Pacific Coast of the United States submarine canyons have been discovered, and submarine mountains have been found here and in the offshore waters of the Alaska Coast. It is considered desirable that the hydrographic surveys be carried far enough seaward to survey such features completely and adequately for charting purposes.

## 123. Survey Scales

The scale of a map is the proportion by which distances on the map represent respective distances on the earth. The scale of a hydrographic survey is that scale at which the positions of the soundings in the area are plotted on the hydrographic sheet.

The terms fractional, natural, numerical, and linear are used more or less inter-

changeably as descriptive of this scale ratio. On published charts and generally on drawings it is represented as a fraction, as $\frac{1}{10,000}$. The same meaning is expressed in text either by 1:10,000, 1–10,000, or 1/10,000.

The basic scale for hydrographic surveys of the Coast and Geodetic Survey is 1:20,000 and almost all other scales used have a simple relationship to it. No inshore survey adjacent to the coast shall be on a scale smaller than 1:20,000, except by authority of the project instructions.

Larger scales shall be successive multiples of 1:20,000, each larger scale being double that of the preceding scale (i. e., 1:10,000, 1:5,000, and 1:2,500). All important harbors, anchorages, channels, and many parts of the coast where dangers are numerous or navigation is difficult, shall be plotted on scales of 1:10,000 or larger.

Scales smaller than 1:20,000 shall be those whose denominators are multiples of 20,000 (i. e., 1:40,000, 1:60,000, 1:80,000, 1:100,000, etc.).

The choice of scale is obviously dictated by the amount of detail required on the hydrographic sheet. The larger the scale the more detail can be shown. The scales selected for important harbors, anchorages, and restricted navigable waterways must be large enough to show the maximum amount of detail desired on the smooth sheet and to permit as close a system of sounding lines and development of the area as may be necessary.

It is an inflexible rule in chart construction that data on a smooth sheet must never be enlarged to the scale of the published chart. A scale should, therefore, be selected for the smooth sheet larger than—and preferably at least twice as large as—that of the largest-scale published chart of the area.

For the inshore survey along an open coast, the scale will vary according to the importance of the area and the number of dangers which may be encountered.

Varying scales must be selected for offshore surveys according to the depth of the water and the distance offshore. In the first zone offshore from the inshore surveys the usual scale is 1:40,000, adjoined by surveys on a scale of 1:180,000 or 1:20,000 in the area farther offshore.

If the survey is comparatively distant from the shore the choice of scale may be limited by the necessity of including shore stations on the smooth sheet, unless *circle* sheets (see **37**) are used. A smaller scale than would otherwise be preferable must be selected occasionally in order to include within the limits to the smooth sheet an adequate number and arrangement of shore stations, so that strong sextant fixes may be obtained throughout the area. The advantage thus gained in being able to plot the positions of the survey vessel with assured accuracy more than offsets the labor involved in inking congested soundings at the smaller scale, or even the disadvantage of having to omit a percentage of the recorded soundings.

In summation, the survey scale should be large enough:

(*a*) To provide for a sufficiently close spacing of the systematic lines and soundings.

(*b*) To provide for an adequately intensive development of the dangers and shoals.

(*c*) To provide for a reduction to the scale of the largest-scale published chart—it should generally be at least twice the scale of the chart.

(*d*) To show all details clearly.

And the survey scale should be small enough:

(*a*) To include the necessary shore control within the limits of the sheet.

(*b*) To include control which will give strong well-conditioned fixes.

### 124. Units of Measurement

The following units of measurement, with fractional parts in decimals of the same unit, shall be used in surveys, reports, and statistics of the Coast and Geodetic Survey:

(*a*) Depth of the water—IN FATHOMS, OR FEET. (For smooth-sheet plotting, see **7711** and **7712**.)

(*b*) Measured horizontal distances on land or in the water, and short estimated horizontal distances over the water—IN METERS.

(*c*) Long estimated distances over the water and ship's run distances—IN NAUTICAL MILES.

(*d*) Elevations above the topographic datum plane or above the sounding datum—IN FEET.

(*e*) Subaqueous distances—IN SECONDS OF TIME (at a given velocity of sound), OR METERS.

(*f*) Statistics of horizontal distances, except for ship's run (see (*c*) above)—IN STATUTE MILES.

(*g*) Statistics of surveyed areas, either water or land—IN SQUARE STATUTE MILES.

(*h*) Current velocity and speed of vessel—IN KNOTS.

(*i*) Bearings from zero at true north clockwise through 360°—IN DEGREES. (Not to be confused with geodetic azimuths, which are reckoned from zero at true south.)

It is to be noted that the short distances estimated during a hydrographic survey and entered in the Sounding Record shall be in meters. This pertains to the estimated distance of the sounding boat or launch from the high-water line or the estimated distance the sounding vessel passes abeam of any object, danger, or aid to navigation.

### 125. Confidential Surveys

Surveys of a confidential nature are occasionally made by the Bureau and the results of surveys of certain areas are at times made confidential at the request of one of the Military Services. Special instructions, stating the precautions to be taken, will be issued whenever confidential field operations are to be executed.

Such surveys are classified and marked as confidential when they are registered, and no copies of these shall be furnished to the public. Photographic copies of confidential surveys will be furnished to field parties who have need for them in connection with their survey operations. Each Chief of Party is responsible for those forwarded to him, although when necessary he may permit their use by responsible assistants. These photographic copies are always plainly marked "confidential" and they must be returned to the Washington Office for disposal, after the operations have been completed. (See also **1321**.)

Whenever any confidential matter is forwarded through the mails it shall first be enclosed in a package marked CONFIDENTIAL and addressed personally by name to the person who is to be responsible for its custody. This envelope or wrapped parcel is then enclosed in an outer wrapping and addressed to that person in the usual manner for official mail. The outer wrapping must contain no reference whatsoever to the confidential nature of the contents. Such material must always be sent by registered mail.

## 13. PROJECT PLANNING

### 131. Data From Prior Surveys

Copies of all prior survey data that are considered necessary in connection with the combined operations of the project will be furnished with the project instructions. Photostat, lithographic, or blueprint copies of the control data—geographic positions, descriptions, and triangulation sketches—will be furnished when these have not been published in the geodetic publications. Copies of all topographic and hydrographic

surveys, with which junctions are to be made, will always be furnished, as well as copies of the most recent ones of the entire area, if the latter are believed to be helpful.

When inshore hydrographic surveys are to be made after air photographic surveys of the area have been completed, printed smooth and boat sheets may be furnished, or tracing paper prints or ozalid prints will be furnished from which to transfer the shoreline and control points (see **733**). Lithographic copies of planimetric maps within the area will be furnished as well as copies of the field prints of the photographs if the latter are believed to be of value in connection with the operations.

If any of the survey data are confidential, the Chief of Party shall be responsible for their custody and for their eventual return to the Washington Office (see **125**).

### *1311. Photographic Copies of Field Data*

When the Chief of Party has reason to believe that the data furnished with the instructions are not complete, he should notify the Washington Office immediately, requesting the additional data. If, during the course of his field operations, copies of additional field data are found to be desirable they should be requested from the Washington Office in ample time for the photographic reproductions to be made and forwarded to him. Usually either photostat or bromide copies of field data are furnished.

### *1312. Photostat Copies*

Photostats made in the Washington Office are limited to a paper size of 18 by 24 inches and to a subject size of 17 by 22½ inches; a reduced photostat is ordinarily limited to no smaller than one-half the scale of the original; and an enlarged photostat is ordinarily limited to no larger than twice the scale of the original. A photostat is normally a negative in that the black and white of the original is reversed but the copy is otherwise correct. Positive photostats may be made from the negatives and have white backgrounds.

When a request is made for a photostat, a negative will always be furnished unless a positive photostat is specifically requested and the reason for the need for the latter is given. Photostats cannot be relied on to be at correct scale, and when such copies are used for the transfer of shoreline or control stations, extreme care must be used. If the quadrilateral formed by the meridians and parallels enclosing the area in question is measured, and found to check with the values in the Polyconic Projection Tables (see **7321**), it is safe to assume that the details within that area are true to scale.

### *1313. Bromide Copies*

When photographic copies larger than 17 by 22½ inches are required, bromide copies are usually made. A bromide is made by first photographing the original at a reduced scale on a glass or film negative, and then making an enlargement on bromide paper, usually at approximately the same scale as the original. The bromide paper does not come in contact with the negative. Since the size of most survey sheets, except aluminum-mounted sheets, is at least 31 by 52 inches, bromides are necessarily made when copies of entire surveys are required to scale. They are limited in size to 38 by 72 inches.

A bromide can be made approximately to any desired scale. It is one of the most unsatisfactory of all copies insofar as clarity and true scale are concerned. Bromides

should not be used for the accurate transfer of control stations and rarely for the transfer of shoreline, if any other type of copy can be substituted. Bromides are always positive copies.

### *1314. Celluloid Prints*

Contact prints can be made on low shrinkage celluloid. These have the advantage of a very low shrinkage factor which is practically uniform in all directions. Such prints are the most accurate copies for use in the transfer of shoreline and control stations. Celluloid prints are considerably more expensive than paper prints and will ordinarily not be furnished unless a reason is given justifying their need.

### *1315. Photographic Colors*

Most data are inked in black on the survey sheet, but various colored inks are used for special purposes. In "Line Photography," which is used in chart reproduction, the colored inks do not reproduce equally well, and in using any photographic copy of a survey this fact must be taken into consideration. In general, the colors in the blue end of the spectrum are photographed with difficulty on ordinary emulsions, especially when an artificial source of light is used; while those in the red end of the spectrum are reproduced relatively well. Yellow photographs almost as well as black. For practical purposes, it is enough to remember that the blue colors, especially blue and violet, photograph poorly and may not be reproduced at all; that the red and yellow colors, especially yellow, orange, and red are reproduced relatively well, sometimes as well as black; and that green and brown are intermediate colors, generally but not always reproducing well. The intensity of reproduction of a color seems to depend on the percentage of yellow in it; for example, an orange red or a yellow green will reproduce better than the purer red and green shades. The amount of pigment in any color has much to do with the intensity of the reproduction.

### *1316. Requests for Photographic Copies*

Requests for photographic copies of surveys should state specifically the kind desired, or the purpose for which they are to be used. In the latter case, copies prepared by the most suitable method will be furnished. (See also **1314**.) When photographic copies of surveys are requested it will be assumed, unless otherwise stated, that they are desired at the scale of the original. When they are for use in the transfer of data to other sheets, they should be requested at the scale of the new survey; if an enlargement is required, the reason for this must be stated. For many uses copies at reduced scales will be found satisfactory if the reduction is not so great as to make the detail illegible. In general, copies of surveys reduced one-half are perfectly legible.

A request for photographic copies of surveys should specify:

(*a*) The registry number of the survey, if known; or in lieu thereof, the approximate latitude and longitude of the area, in addition to any field number or reference to named geographic features.

(*b*) The kind of copy desired. (See also **1314**.)

(*c*) The scale of the desired copy.

(*d*) Whether a topographic or hydrographic survey, and the approximate date thereof.

The following examples of requests contain the required information:

"A full-scale photostat copy of a section of the most recent hydrographic survey off Point Judith, R. I.; photostat to be centered at latitude 41°20′ N., longitude 71°25′ W."

"A half-scale photographic copy of hydrographic survey by John Doe, field number Oc-4234, located in approximate latitude 41°20′ N., longitude 71°25′ W."

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## 132. Nautical Charts

Copies of the largest-scale nautical charts of the project area, of the latest print dates, should always be on board the survey vessel during its operations. It is not sufficient to have charts of the most recent edition. The print dates are located in the lower left-hand corner of the chart and the latest is the right-hand one of a consecutive series of dates (see **1127**). In all Descriptive Reports, special reports, and correspondence, in which a comparison is made between the field data and the published chart, this print date must be stated. This is the only positive means of reference to the data which were on the chart when the comparison was made.

### *1321. Confidential Charts*

When survey vessels are operating in an area of which confidential charts have been published, copies of these are obtained from the United States Navy Department for use on board the vessels during the survey operations. Each chart contains a serial number. Chiefs of Party are responsible for the custody of the confidential charts sent to them and must render a semiannual report, on March 31 and September 30, listing these with their serial numbers. This report shall be made on Form N.H.O. 698a, and be forwarded to the Director. (See also **125**.)

### *1322. Complimentary Copies of Charts*

At the request of a Chief of Party complimentary copies of new charts or new editions extensively corrected from a survey will be furnished for distribution to members of the crew who had a responsible part in the survey operations. Officers engaged on the survey will be furnished such copies on request. It must be realized that there is often a considerable lapse of time between the date of the survey and the issuance of new charts or new editions embodying the results of the survey.

## 133. Project Study

As soon as the project instructions and the accompanying survey data have been received, a preliminary study of the project should be made in as great detail as is possible from the available data in order to formulate a general plan of operations. If the project is of an unsurveyed and comparatively little known area, recourse must be had to reconnaissance survey data. Much of value in planning the operations can often be found in published exploratory and other reports of scientific expeditions which have operated in the area.

### *1331. Study of Charts and Prior Survey Data*

If the project is for the resurvey of an area, a thorough study of the published charts and the photographic copies of prior survey data shall be made in order to plan the operations effectively and economically. These data may be used to determine the approximate limits of the area to be surveyed by each unit of the party and the probable limit to which the hydrography may be controlled by the various methods.

If the project instructions call for new triangulation in the area, a paper reconnaissance can be made for use as a general layout for the scheme, and from which the actual stations can be selected after the party has arrived in the immediate locality. If the existing charts of the area are based on reconnaissance surveys or sketches, little confidence can be placed in the charted data for such a purpose, because, even though

the charts present a general idea of the area, the representation of specific details may be considerably distorted.

### *1332. Air Photographs for Study of Project*

Good air photographs will furnish extraordinarily detailed information, thus supplementing prior surveys and reports, particularly when those using them are experienced in the interpretation of photographs and acquainted with similar types of terrain. The photographs available may vary from a few nonstereoscopic obliques, taken casually during flights over the area for other purposes, to complete stereoscopic coverage by vertical photographs taken for plotting on the same scale as the intended hydrographic survey. The information obtainable for planning the project will vary correspondingly from general data on the character of the region to detail almost sufficient for planning day-to-day operations. The project instructions will indicate the available air photographs, mosaics, maps, or hydrographic sheets prepared from air photographic surveys. Usually an index chart or mosaic will be furnished from which the approximate location and area of each photograph may be determined.

In the absence of sufficiently detailed prior surveys, the following data for advance study and planning of the project may be obtained from an examination of suitable photographs or preliminary maps and mosaics compiled from them:

(*a*) The approaches to the coast and routes along it both for the ship and the small boats; whether there are off-lying islands, rocks, reefs, or shoals, and the probable clear channels between them; protected areas possibly suitable for anchorage, and the best landing places for small boats.

(*b*) The locations of sites suitable for camping; the boats and equipment which will be needed for landing and for inshore hydrography; objects available for hydrographic signals; the proportion of control stations that may be expected to be furnished by the photographic survey and the amount of supplemental planetable surveying likely to be needed; the kinds and amounts of the various signal-building materials required; and the probable rate of progress of the inshore operations. This information may be determined from the appearance of the shore with more or less certainty depending on previous experience. A detailed discussion of control from air photographs for use in hydrographic surveys is included in **239**, and the use of air photographs to detect dangers to navigation is discusssed in **3624**.

(*c*) The photographs of the terrain adjacent to the shore will show the roads, trails, rivers, settlements, etc.; special means of transport and supply other than by water, which may be desirable; whether the terrain is bare or wooded; the relief, landmarks, and sites suitable for triangulation or signals to control offshore hydrographic surveys; the distances and best routes to such sites, and the character of signals, materials, and outfit needed for the operations ashore. The use of photographs in connection with triangulation reconnaissance is discussed in **2221**.

A stereoscope, if available, should be used in studying the photographs wherever they have suitable overlap. Landmarks, the tentative locations of old and new stations, landing places, campsites, and any questions regarding the interpretation of the photographs should be noted in pencil on them, or on the mosaics or preliminary compilations, during the advance study.

The field reconnaissance required to complete the information needed to conduct the season's operations (such as the depth of the channels indicated by the photographs, depth and holding bottom of protected anchorages, doubtful lines for triangulation observations) will become apparent during the advance study. After arrival on the working ground, the notes made during the advance study will facilitate the detailed study of the photographs for the planning of day-to-day operations. As the party becomes familiar with the locality, additional precision in interpretation and benefit from the use of the photographs will be obtained.

### *1333. Weather Conditions*

No part of planning is more important than that based on the prevalent weather conditions in different seasons. In northern areas, or other areas where bad weather prevails during a large part of the year, it is necessary to utilize to the fullest extent the season during which survey operations may be conducted economically. It is essential that the survey party arrive on the scene of operations as early as practicable and remain there until survey operations are no longer economical.

Special attention should be given to selecting an appropriate part of the season during which to conduct those operations requiring unusually favorable weather conditions. When the season of most favorable weather for certain operations is known in advance, economy will result if the entire project is planned so that these can be undertaken at that time.

Where the project is located in a region with which the Chief of Party is unfamiliar, he should study in advance the available information regarding the prevalent weather conditions in the area. Meteorological data may be available, but if not, much information of value may be found in the reports of survey or exploratory parties who have previously operated in this or similar adjacent areas.

Exceptionally clear weather is needed for certain operations such as triangulation observations, the control of offshore hydrography by visual fixes, and sun-azimuth observations between buoys. Exceptionally smooth weather is needed for other operations, among which are landings on very exposed portions of the outer coast, the installation of tide gages, the establishment and location of buoy control, and the installation of hydrophones and cable laying if R.A.R. shore stations are used. Some of the above operations must necessarily be performed at the beginning of the season or prior to certain other operations, but when there is a choice, they should be planned for that part of the season during which prevalently good weather for those operations may be expected. (See also **145**.)

### *1334. Anchorages*

Before proceeding to the project area, it is desirable to determine in advance whether or not safe anchorages are available at which the survey vessel may base. If the area is well known, a selection can be made without difficulty. There may be many possibilities, the choice often depending merely on the facility of obtaining supplies and the adequacy of the mail and communication service.

When the project is in an area where dangerous weather conditions may be expected, the work must be planned so that a protected anchorage is always accessible, and ordinarily such anchorages can be selected in advance from a knowledge of the area.

## 134. OPERATIONAL PLAN

From the study of the project, a general advance plan should be formulated for the accomplishment of the early operations of the project. This plan should be based on the results to be attained, the size of the party and the various units which may be organized, the weather conditions, and other factors that may affect the operations. Such a general plan will, of course, be subject to frequent change as the work progresses.

Where the area to be surveyed extends offshore from the coast and various zones of the project are to be surveyed by separate hydrographic units and by different methods of control, the hydrography should be planned so that the various units may be given the limits to which their surveys are to extend.

Careful study and planning will result in a logical sequence of operations so that each phase of the work accomplished will give as much information as practicable on which to base the subsequent phases of the work. A project so planned will be completed without waste of time or effort and without any of the essential work having been omitted or neglected.

### *1341. Priority of Operations*

The project instructions may call for priority in certain phases of the operations and these must be planned for completion at as early a date as practicable.

The nature of combined operations is such that the effective accomplishment of certain phases of the work will depend on the prior accomplishment of others. If no triangulation exists in the area, it will probably be necessary to plan and execute a complete new scheme to control the other operations. It is necessary that the work be planned so that the triangulation will always be in advance of other operations. If the size of the project is such that the work will continue for several years, efficient planning will provide for the accomplishment of triangulation sufficiently in advance so that control will be available at the start of each season for the first topographic and hydrographic surveys.

The topographic surveys, which serve to locate the control stations for the hydrographic surveys, should always be planned so that the hydrographic parties will not be delayed waiting for control to be established.

Where unknown dangers to navigation are likely to exist in the area, the harbors and anchorages should be surveyed in advance of the time they may be needed by the survey vessel. The inshore surveys should be carried to a depth in which it is safe for the larger vessel to operate.

### *1342. Parallel Progress of Operations*

Except for the priority described in **1341**, it is desirable that all classes of work be completed to the same general limit at the end of each season. It is inefficient to have topographic surveys completed at the end of a season too far in advance of the hydrographic operations, because signals are likely to be destroyed before the next season. Even where signals have not been built but the stations merely marked, it would be necessary to go over the same ground the next season in order to build them.

### *1343. Incomplete Sheets*

The work should be planned, if practicable, so that any topographic or hydrographic sheet begun will be completed during that season, barring unforeseen circumstances. The results of the field operations are not available for charting until the surveys have been verified and reviewed in the Washington Office and it is usually not practicable to do this for a sheet partly completed.

All necessary development and investigation of shoals should be kept up to date as they are revealed through the regular system of sounding lines. During the early part of a season, it is essential to do this for reasons of economy in operations, otherwise the party is likely to find such work not conveniently located to be undertaken economically in connection with the other operations. During the latter part of the season, this procedure is quite important in order to avoid closing the season with incomplete surveys.

## 135. Division of Operations

The division of operations, between the various units of the party, should be made so as to secure the greatest possible progress consistent with economy and safety in the use of the survey ship and launches. It is obvious that the number of separate units which can be operated at one time, either from the ship as a base or from shore bases, depends on the size of the party and the available floating equipment. In well-developed parts of the country it is frequently economical to have a portion of the work, especially triangulation and topography, performed by a shore party independently operated but responsible to the Chief of Party. In such areas trucks are being used extensively for the transportation of the survey units to and from their work, even where the shore party is engaged in hydrographic surveying. In undeveloped areas, where there are no available living quarters, similar parties are usually operated from camps, but since there are no highways in such areas the camp parties must be furnished other kinds of transportation than trucks.

All the various operations in which a survey party engages must be equalized in such a way that parallel progress is maintained. This is especially true with respect to the division of sounding between the ship and the launches or small boats. It is obvious that prudence restricts the ship to those areas which can be navigated in safety and, in general, it is most usefully employed in the survey of the offshore and more exposed areas. Exposed areas far from shore should not be surveyed with unattended launches, because of the danger involved and because the lower elevation of the observers limits the range of visibility of the control signals.

The operations should be so planned that all large-scale surveys are made by the launches and small boats, because of the impracticability of controlling the course and position of a large survey ship accurately enough to run the necessary survey lines economically.

### *1351. Shore Party Operations*

When a part of the operations is performed by a shore party in a populated part of the country the shore party may be established so as to be almost independent of the mother survey ship, except for very general supervision by the Chief of Party. Where such parties have to be based at camps in undeveloped country, they must be supplied and provisioned from the survey ship, and it is frequently necessary to bring the entire camp on board for transfer to another locality. In undeveloped areas on exposed coasts, campsites must be selected in harbors or protected anchorages where the floating equipment will be safe.

If land operations only are performed from a camp on an exposed coast where there are no highways, horse transportation may be used in the survey operations and in an emergency for moving the camp to another locality. The use of horses is undesirable because of the special personnel required to care for them, and because of the large amount of feed with which they must be provisioned if natural feed is not available in the locality. Furthermore, it is generally not practicable to have sufficient horses to move a camp in less than several trips between the campsites. A light reconnaissance truck, of Army specifications, is being tested as a substitute for horse transportation. It can probably be operated along most of the coasts even where there is no semblance of roads or trails.

Where launch hydrographic surveys are made by a party based ashore, the campsites or anchorages must be chosen so that the time required for runs to and from the

working ground will be at a minimum. This also applies to the selection of harbors and anchorages for the ship, although its safety is the first consideration.

In isolated areas, where a shore party is supplied and provisioned from the survey ship, it is essential that there be means of communication between them. In recent years all such shore parties have been equipped with a sending and receiving radiophone. This has proved very effective since it enables the chief of the subparty to report to the Chief of Party on his daily progress, on the status of his supplies and provisions, and on any accident, such as damage to floating equipment or injury to personnel, and on any sickness requiring transfer of personnel to the ship for medical attention. It also permits plans to be made in advance for moving the camp if that is to be done with the aid of the ship.

## 136. PROJECT LAYOUT

To plan and carry out effectively and systematically extensive combined operations it will generally be necessary to lay out on a chart of suitable scale the limits of the project, the limits of previously surveyed areas with which the instructions specify a junction, the principal control stations, and any other data which may be of importance. If the area is an unsurveyed one and the only existing chart is of small scale and of a reconnaissance nature, it may be necessary to make this layout on a reconnaissance sketch especially constructed therefor.

### *1361. Sheet Layout*

Since different scales are generally necessary for the surveys of different parts of an area, and since the size of a sheet is limited, more than one sheet will usually be required for the survey of an extensive area. In order that these sheets may be planned practicably and economically, a sheet layout should be made on a chart of suitable scale, or in an unsurveyed area on a reconnaissance sketch, on which are outlined all or a part of the sheets required to cover the area. (See fig. 2.)

Each hydrographic sheet should be laid out in such a manner that it will include as large a water area as practicable, at the same time providing for adequate overlap with adjacent sheets and ensuring that all of the required control stations will be included. Skewed projections must be avoided if it is practicable to do so (see **1362**). The overlap of adjacent sheets should generally be no more than is required to provide for a suitable junction of adjacent surveys and to include the necessary control stations (see **123**). Hydrography must not be extended to the offshore limits of a sheet when it can be more strongly controlled on an adjoining offshore sheet; neither should it be extended parallel to the shore to the extreme limits of a sheet where it can be more strongly controlled on an adjacent alongshore sheet. In these cases the extent of the overlap should be sufficient to provide hydrography controlled with equal strength on both sheets.

If the project is for the resurvey of an area fairly well represented on existing charts it may be practicable, at the start of the project, to lay out sheets covering the entire area. If the project is for the survey of a comparatively unknown area, it may be preferable to extend the sheet layout from time to time, as more detailed information relative to the area becomes available.

A convenient method for making this layout is to construct on tracing cloth an outline of each appropriately sized sheet according to the scale of the published chart on which the layout is to be made. The tracing cloth containing the limits may then

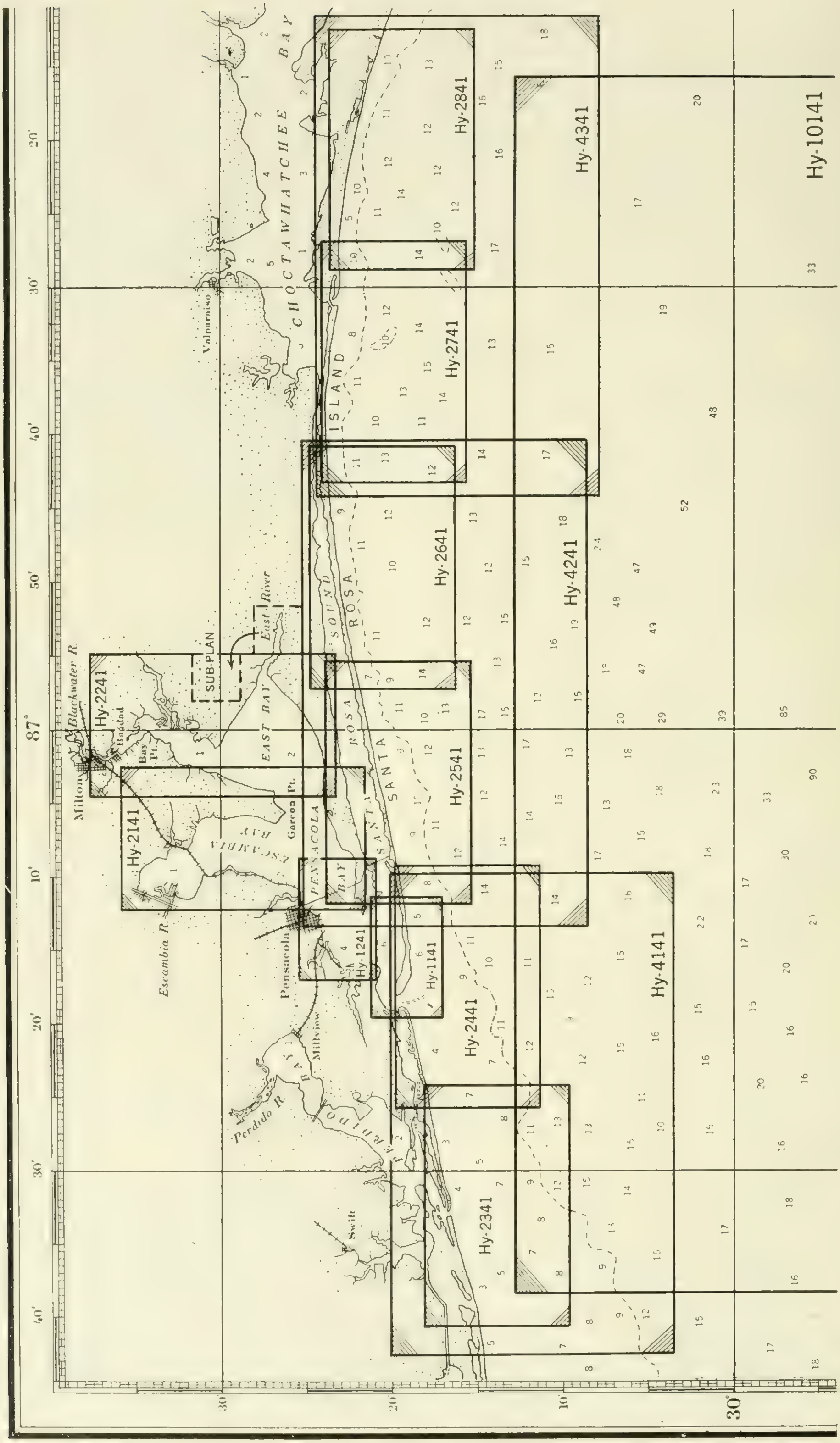


FIGURE 2.—Typical layout of hydrographic survey sheets.

be placed on the chart and shifted about until the best position for the sheet is determined. In a simple area it will be easy to lay out successive sheets by this method to cover the entire area of the project. Where the area is complex it is frequently necessary to try various successive layouts of sheets before the most practicable and economical one is found. As the best position for each sheet is determined, the four corners may be pricked through the tracing with dividers and joined by straight lines on the layout.

TABLE 1.—*Scale equivalents for laying out sheets*

| Scale | One inch equals | | One centimeter equals | | One nautical mile equals | | One statute mile equals | |
|---|---|---|---|---|---|---|---|---|
| | *Nautical miles* | *Statute miles* | *Nautical miles* | *Statute miles* | *Inches* | *Centimeters* | *Inches* | *Centimeters* |
| 1:2,500 | 0. 034 | 0. 039 | 0. 013 | 0. 016 | 29. 185 | 74. 13 | 25. 344 | 64. 37 |
| 1:5,000 | . 069 | . 079 | . 027 | . 031 | 14. 593 | 37. 06 | 12. 672 | 32. 19 |
| 1:10,000 | . 137 | . 158 | . 054 | . 062 | 7. 296 | 18. 53 | 6. 336 | 16. 09 |
| 1:20,000 | . 274 | . 316 | . 108 | . 124 | 3. 648 | 9. 27 | 3. 168 | 8. 05 |
| 1:40,000 | . 548 | . 631 | . 216 | . 249 | 1. 824 | 4. 63 | 1. 584 | 4. 02 |
| 1:60,000 | . 822 | . 947 | . 324 | . 373 | 1. 216 | 3. 09 | 1. 056 | 2. 68 |
| 1:80,000 | 1. 096 | 1. 263 | . 432 | . 497 | 0. 912 | 2. 32 | 0 792 | 2. 01 |
| 1:100,000 | 1. 371 | 1. 578 | . 540 | . 621 | . 730 | 1. 85 | . 634 | 1. 61 |
| 1:120,000 | 1. 645 | 1. 894 | . 648 | . 746 | . 608 | 1. 54 | . 528 | 1. 34 |
| 1:200,000 | 2. 741 | 3. 157 | 1. 079 | 1. 243 | . 365 | 0 93 | . 317 | 0. 80 |
| 1:400,000 | 5. 482 | 6. 313 | 2. 158 | 2. 485 | . 182 | . 46 | . 158 | . 40 |
| 1:500,000 | 6. 853 | 7. 891 | 2. 698 | 3. 107 | . 146 | . 37 | . 127 | . 32 |
| 1:1,000,000 | 13. 706 | 15. 783 | 5. 396 | 6. 214 | . 073 | . 18 | . 063 | . 16 |

The area that will be included on a sheet of given dimensions at a specified scale may be readily determined from table 1 by multiplying the dimensions of the sheet by the number of miles at the selected scale. For example, a sheet 31 by 53 inches on a scale of 1:20,000 will include an area 8.5 by 14.5 nautical miles.

### *1362. Sheet Orientation*

All hydrographic sheets shall be laid out so that the projection lines are approximately parallel with the sides of the sheet, except when such a layout is extremely uneconomic or impracticable (see **1361**). The reason for this is that a cloth-mounted sheet distorts almost uniformly along its axes and if a sheet is laid out with the projection lines parallel to the edges, distortion is comparatively easy to compensate for in chart compilation. With a skewed projection it is much more troublesome and in addition such a sheet is inconvenient to handle.

### *1363. Sheet Size*

The standard size for all hydrographic smooth sheets shall be 31 by 53 inches and they shall ordinarily not exceed this size, except for offshore surveys. The maximum size, which shall never be exceeded under any circumstances, is 42 by 72 inches (see **712**). In the original layout of the project these limits need not be strictly adhered to, and it is sometimes of advantage to plan the boat sheets on a size somewhat larger than the anticipated limits of the smooth sheets and with more overlap. Frequently it is only after part of the survey has been completed that the smooth sheets can be laid out most economically.

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### *1364. Subplans*

Sheets containing small detached areas of hydrography shall be avoided, if practicable. This can usually be accomplished by placing a *subplan*, or insert, on the smooth sheet, at the same or an enlarged scale. (See **7751**.)

If it is impracticable to include, in the original sheet layout, an entire area on several standard size sheets, and a small section remains that is necessary for effecting a junction with a prior survey, it is frequently practicable to include such area as a subplan on an unused portion of the adjacent sheet. Such subplans must always be included on the sheet of comparable scale closest to the area.

Where a small harbor, anchorage, or other area needs to be surveyed at a larger scale than the remainder of the inshore coastal waters, it likewise may frequently be included as a subplan on the sheet which includes the area.

It is to be noted that boat sheets are not necessarily similar in layout to the smooth sheets and there is no objection, and in many cases there is a decided advantage, in surveying on separate boat sheets such areas as are discussed under this heading. The results of several boat sheets may be included on one smooth sheet. (See **3222**.)

### *1365. Layout Made in Washington Office*

Infrequently the sheet layout for the project is made in the Washington Office at the time the project instructions are written, and is furnished with them. This may occur when the results of the survey are urgently needed and it is necessary to furnish the boat and smooth sheets to the field party without delay.

It is also necessary if lithographic reproductions of planimetric maps are to be furnished for use as boat and smooth sheets.

To take advantage of the economy of lithographic reproductions it is often necessary to sacrifice certain desirable features of layout. When a proposed layout, based on planimetric maps, is made in the Washington Office, it will be submitted to the Chief of Party for inspection and approval, if time permits, before the boat and smooth sheets are constructed. (See **733**.)

### *1366. Dog-Ears*

It is sometimes impracticable to determine in advance the exact limits of a hydrographic sheet. Because of developments during the progress of the survey or the location of control, it is occasionally desirable or necessary to use a control station which falls a short distance beyond the limits of the sheet as originally laid out. This is accomplished by adding a small section of paper, called a *dog-ear*, to the boat sheet and plotting the station thereon. While there is no objection to the use of dog-ears on a boat sheet, there is serious objection to their use on smooth sheets, and they are not to be tolerated on the latter except in an emergency. (See **7121**.)

## 137. Supplies and Equipment

After the receipt of the project instructions, a review must be made to determine whether the necessary survey equipment and instruments are on board, and if not, they should be requisitioned from the Washington Office in ample time for their assembly, possible overhaul, shipment, and receipt before needed for actual survey operations (see **432**).

It is also necessary to determine the materials which will be needed for signal building, construction of buoys, etc., which should be on hand at the time field operations are begun.

All of the necessary forms, blank records, and rubber stamps which will be needed should be requisitioned from the Washington Office.

### *1371. Overhaul of Survey Equipment and Instruments*

The various types of survey equipment and instruments that are ordinarily used in the hydrographic survey operations of the Coast and Geodetic Survey are described in chapter 4.

It is only necessary to emphasize here that the equipment and instruments on board which will be needed for the survey operations, should be overhauled and cleaned and put in the best possible condition by the party before the beginning of a season's work, in order that maintenance work on them during the field season may be reduced to a minimum (see **43**).

As soon as possible after the close of each field season, all excess instruments and those needing overhaul or repair by experienced instrumentmen should be forwarded to the Washington Office, and the required additional instruments, or replacements, requisitioned at that time. The last minute requisitioning of instruments just before the start of a new season or project shall be avoided.

Base tapes must be returned to the Washington Office for re-standardization at the end of each field season during which they have been used. Complete particulars relative to their use during the season shall be furnished, including the locality and the general conditions encountered, such as weather, temperature, and terrain.

Form 12, Requisition for Instruments and General Property, shall be used for the requisition of all instruments and general property from the Washington Office, and Form 573, Letter of Transmittal and Receipt for Transfer of Instruments or General Property, for their return to the Washington Office, or for their transfer between Chiefs of Party.

## 14. ORGANIZATION OF OPERATIONS

### 141. General Reconnaissance

The extent and manner in which reconnaissance for a hydrographic survey is conducted depends principally on the character and extent of the information available prior to the beginning of the project. If the project is a revision survey, very little reconnaissance will be required. The prior surveys will show the disposition and amount of control probably available, the type of shoreline, the depths and characteristics of the area to be sounded, the available anchorages, suitable sites for camp parties, and suitable locations for the necessary tide stations. In fact, sufficient control may be recovered so that new triangulation will not be necessary, and hydrographic operations can be started within a few days after the vessel arrives at the project area.

Should the project be an extension of the previous season's work, personal knowledge of the character of the working ground and conditions to be encountered will enable the Chief of Party to make plans in advance, which will expedite the progress of the survey and coordinate the operations of the various units to the best advantage.

If the project is in an unsurveyed area about which little information is available, a reconnaissance must be made before planning the work. A tentative scheme of triangulation should be laid out and the type of signals to be used should be determined.

TABLE 2.—*Personnel of survey units*

| Personnel | Handlead in pulling boat | Launch hydrography: Handlead or machine sounding | Launch hydrography: Graphic-recording Fathometer | Ship hydrography, Fathometer, Visual control: Shore stations | Ship hydrography, Fathometer, Visual control: Buoy stations | Ship hydrography, Fathometer: R.A.R. control |
|---|---|---|---|---|---|---|
| In charge (plotting) | 1 | 1 | 1 | 1 | 1 | 1 |
| Left angleman | | | | | 1 | |
| Right angleman | | 1 | 1 | 1 | 1 | |
| Recorder | 1 | 1 | 1 | 1 | 1 | 1 |
| Fathometer attendant | | | 1 | 1 | 1 | 1 |
| Leadsman | 1 | 1 | | | | |
| Leadsman's assistant | 1 | 1 | | | | |
| Coxswain or helmsman | 1 | 1 | 1 | 1 | 1 | 1 |
| Engineer | | 1 | 1 | Engine-room force | | |
| Additional seamen | 2–4 | | 1–2 | | | |
| Chronograph attendant | | | | | | 1 |
| Radio technician | | | | | | 1 |
| Bomber | | | | | | 1 |

| Personnel | Other ship operations: *a.* Taut-wire traverse | Other ship operations: *b.* Sun-azimuth observations | Other ship operations: *c.* Bombed distances for the determination of horizontal velocity of sound | Simultaneous operations: Combination of *a* and *b* | Simultaneous operations: Combination of *a* and *c* | Simultaneous operations: Combination of *a*, *b*, and *c* |
|---|---|---|---|---|---|---|
| Officer-in-charge, conning ship | 1 | 1 | 1 | 1 | 1 | 1 |
| Officer, bridge attendant, recording | 1 | | | 1 | 1 | 1 |
| Observer reading T-W sheave | 1 | | | 1 | 1 | 1 |
| Observer checking T-W sheave reading | 1 | | | 1 | 1 | 1 |
| Inclined angle observer | | 1 | | 1 | | 1 |
| Vertical angle observer | | 1 | | 1 | | 1 |
| Recorder (for sun azimuth) | | 1 | | 1 | | 1 |
| Pelorus attendant | 1 | 1 | | 1 | 1 | 1 |
| Helmsman | 1 | 1 | 1 | 1 | 1 | 1 |
| T-W apparatus attendant | 1 | | | 1 | 1 | 1 |
| Chronograph attendant | | | 1 | | 1 | 1 |
| Chronometer attendant | | 1 | | 1 | | 1 |
| Bomber | | | 1 | | 1 | 1 |
| Fathometer attendant | 1 | | | 1 | 1 | 1 |
| Radio technician | | | 1 | | 1 | 1 |

It is also necessary to determine the most practicable method of controlling the topographic surveys.

Suitable anchorages must be selected for the protection of the ship. Possible locations for campsites should be investigated to determine whether camp parties can operate to advantage. If there are off-lying islands, the most practicable method of establishing control stations on them should be selected. An estimate of the number of tide stations needed should be made and possible locations noted. The depths of the water at various distances from the shore should be investigated to determine the approximate limits of launch and ship hydrography. The topography of the area should be viewed to find out what natural and artificial objects are available to control the ship hydrography. The type of control should be chosen for the ship hydrography beyond the range of the shore objects—whether survey or sono-radio buoys can be used to advantage and to what distances offshore depend mainly on the offshore depths.

## 142. Personnel of Survey Units

Each of the survey operations requires a minimum of experienced personnel in order that accurate and dependable results may be obtained. When part of the personnel is inexperienced, or for purposes of training, it is obviously desirable to assign additional personnel to assist in carrying out the operations.

Table 2 gives the personnel needed for the various operations, but is intended as a guide only. With efficient and experienced officers and men, many of the operations can be carried out with fewer personnel.

A hydrographic survey unit engaged in handlead sounding from a small boat usually consists of an officer-in-charge who observes one of the angles and plots, a recorder who records and observes the other angle, a leadsman and an assistant who hauls in the leadline for him, and a helmsman. When soundings are taken rapidly, the recorder may not be able to observe an angle and an additional angleman is required for this duty. If the small boat is propelled by oars, two to four additional men serving as oarsmen are necessary. Outboard motors are used almost exclusively in small-boat hydrography, in which case the oarsmen are dispensed with and the helmsman operates the outboard motor.

The organization of a launch party is similar except that an additional officer is usually required to observe one of the angles and assist the officer-in-charge by generally supervising the operations. It is in this position that the junior officers receive their preliminary training. An engineer is also necessary. In handlead sounding the coxswain and leadsman usually alternate in their duties, or if the leadsman's assistant is competent he may alternate with the leadsman in heaving the lead. When a sounding machine is used the leadsman and his assistant operate the machine. When a graphic-recording echo-sounding instrument is used in a launch, a trustworthy man is required to attend it at all times. The leadsman and his assistant may be dispensed with, but there must be at least one, and preferably two, additional seamen who can take occasional handlead soundings and who assist at bar checks and other duties.

For ship hydrography it is assumed that the usual personnel composing a watch at sea will be on duty, and table 2 is not intended to imply that any of these should be dispensed with. The requirements for ship hydrography are very similar to those for a launch unit except that the increased speed of the operations may require additional personnel, since virtually all depths are measured by echo sounding with the ship proceeding at standard speed. Under the most favorable conditions, where the area being

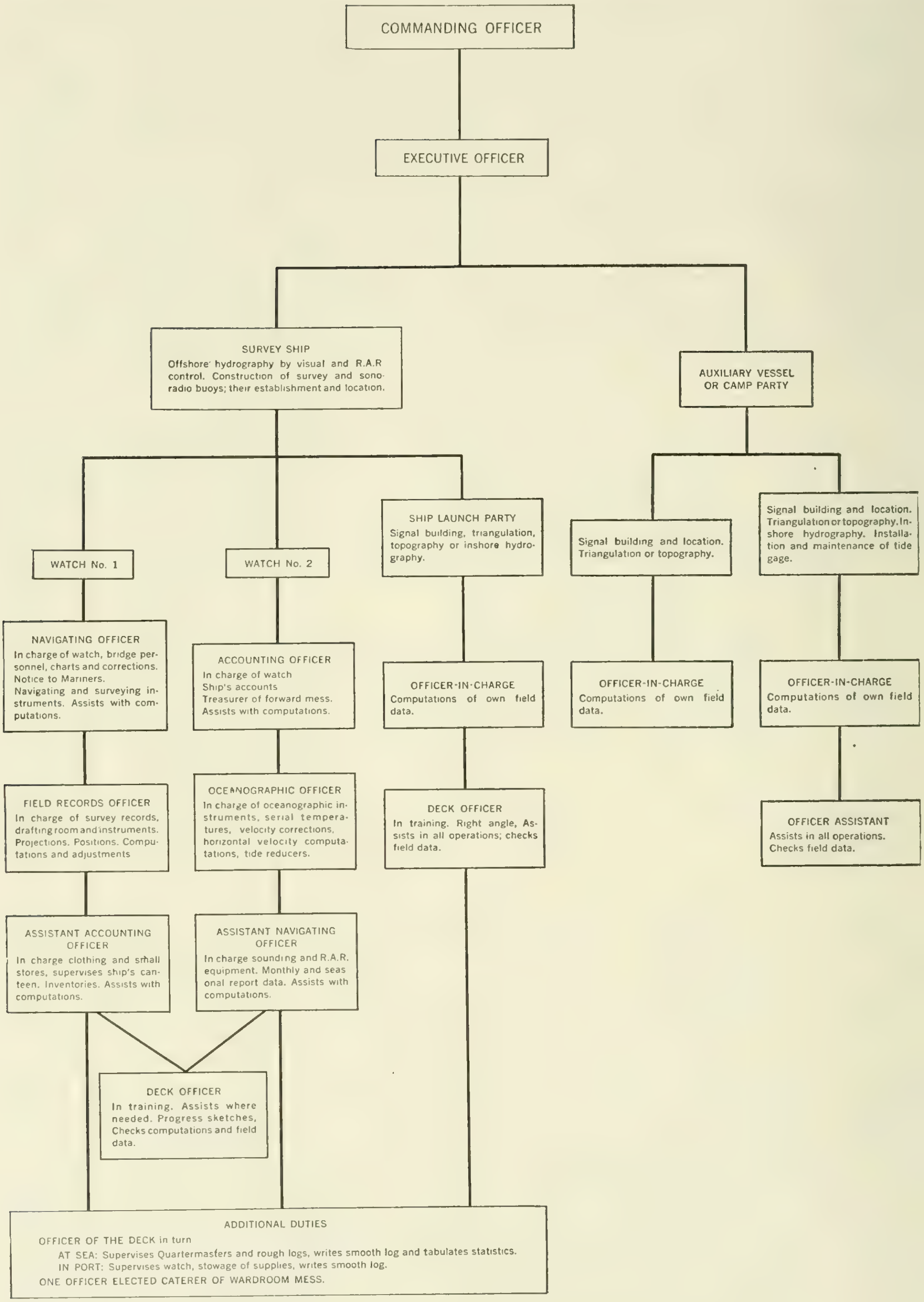


FIGURE 3.—Organization chart of a survey ship.

surveyed is not distant from the control, two officers, one recorder, one fathometer attendant, and one helmsman will ordinarily suffice for visually controlled hydrography; but where the signals are distant, or difficult to observe because of haze or other reasons, it is frequently necessary to have two anglemen to take the sextant observations, leaving the officer-in-charge free for plotting.

For hydrography controlled exclusively by the R.A.R. method, the officer-in-charge is sufficient on the bridge under ideal conditions, but when this method of control is combined with visual control, as it frequently is, additional officers are required. A chronograph attendant, a radio technician, and a bomber are additional personnel needed for the various operations in R.A.R. control; their duties are described in **671.** When R.A.R. controlled hydrography is continued at night or in reduced visibility, additional officers are required on the bridge; one of these directs his attention exclusively to the navigation and safety of the vessel.

Ship operations, such as taut-wire traverse, sun-azimuth observations, and bombed distances for the determination of the horizontal velocity of sound, require personnel who are exceptionally alert and efficient, because a failure to make or record any one of the observations may require the repetition of the entire operation. The number of personnel required for the various operations depends somewhat on the location of the apparatus, and under ideal conditions some of the duties may be combined and performed by one person. For example, in simultaneous operations the observers reading and checking the taut-wire sheave may also be able to take the inclined and vertical angles, which are always observed between sheave readings. If the chronometer is conveniently located, the recorder may be able to mark the times directly on it, or in other instances may use a watch which has been previously compared with the chronometer. The fathometer attendant is, of course, needed only when a sounding line is run simultaneously with the other operations. The fathometer attendant can frequently serve also as pelorus attendant. On shipboard the several men on watch are used as required, the quartermaster on watch serving to carry messages where needed, and other members of the crew being available as hand leadsmen, or to operate the sounding machine if required.

A topographic, signal-building, or triangulation party unit usually consists of one officer and three men. If these parties are transported ashore from the ship, additional personnel are required for the launch crew. If they are based in camp, a cook and camp attendant must be provided.

The efficiency of the survey party and the quality and quantity of the results obtained will depend largely on the experience and qualifications of the officers and men and the interest and pride they take in their work. Assignments should be based on the experience and general aptitude of each individual, and the degree of reliability that can be placed in his work. One of the functions of the officer-in-charge is to encourage the personnel to learn their duties and become proficient in their work, and to provide them with opportunity for obtaining the necessary all-round experience to enable them to assume charge of similar operations when called upon to do so.

### 143. Tide Stations

Tidal data are required for determination of the various datum planes, for the prediction of tides, and for use in a hydrographic survey.

Tide stations shall be established in the immediate vicinity of the hydrographic operations in order that the soundings may be accurately reduced to the sounding

datum. The number of stations required depends on the character of the area; where the flow of tide is restricted, numerous gages may be required to determine accurate tidal constants.

### *1431. Sites for Gages*

The selection of sites for the tide gages to be used in a hydrographic survey is usually made in the Washington Office and is specified in the project instructions. If on arrival at the working ground the selected sites are found to be impracticable, the Chief of Party may make necessary substitutions, but he must advise the Office of such changes and the reasons for making them.

### *1432. General Plan for Tide Stations*

In establishing tide stations in an area, the general plan is to install a standard automatic gage at a central point to serve as a control station to be maintained in operation during the entire period covered by the survey. In some cases, an existing primary tide station in the general vicinity of the project may be used as the control station. As the work progresses, secondary tide stations are established at other places in the immediate locality being sounded, the distribution depending on the change in the tide from place to place. When practicable, observations at each secondary station shall be continued over a period of not less than 2 weeks. A portable automatic gage is usually used for this purpose. A discussion of locations for the secondary tide stations is contained in paragraphs 168 to 177 in Special Publication No. 196, Manual of Tide Observations. Detailed descriptions of the tide gages with full instructions for their installation may be found in the same publication. Officers must thoroughly familiarize themselves with both types of gages and their operation.

### *1433. Bench Marks and Leveling*

At each tide station there must be a tide staff connected by levels with at least three substantial bench marks, so located that they will not all be likely to be destroyed by a common cause. Search shall be made for all old bench marks in the general vicinity, their present condition shall be noted, and the old descriptions revised if necessary. So far as practicable there should be maintained in every locality where a tide staff is installed, or where tide observations have previously been taken, at least five bench marks in good condition. Any deficiency found at the time of visiting such a site should be corrected by the installation of new bench marks. New bench marks should be clearly described so that they may be readily recovered and identified. All the bench marks recovered and established should be connected by levels with the tide staff.

In assigning numbers to new bench marks, the duplication of numbers previously used in the same locality for other bench marks, whether destroyed or extant, shall be avoided. When a bench mark of another organization is recovered and connected by leveling with the Coast and Geodetic Survey bench marks, the number or name assigned it by the organization is to be retained with such additional abbreviation as may be necessary to identify the organization.

When a tide gage is discontinued, check levels between the tide staff and not less than three bench marks shall be run to ascertain whether there has been any change in the elevation of the tide staff during the observations. These levels shall be recorded on Form 258, Leveling Record—Tide Station, and immediately forwarded to the Washington Office.

Instructions relating to tidal bench marks and leveling are contained in paragraphs 97 to 112 of Special Publication No. 196, Manual of Tide Observations.

### *1434. Tide Station Reports*

A report on the establishment of each tide station shall be made in duplicate on Form 681, Report—Tide Station. The record of levels, with descriptions and reports on bench marks, shall be entered on Form 258, Leveling Record—Tide Station. The report on the establishment of the station and the record of levels should be forwarded to the Washington Office immediately after the installation of the tide station has been completed. The location of each tide station and the points at which tide observations are taken with the Dorsey Fathometer (see **1436**) must be plotted on the hydrographic sheet (see **7865**).

### *1435. Tide Records*

Records from the automatic tide gages are to be forwarded to the Office as promptly as possible after the data required by the field party have been extracted. When the observations at any tide station are terminated, a notation of the hour and date of the discontinuance should be entered on the last marigram taken from the gage.

### *1436. Offshore Tide Observations*

Because of the high precision of the Dorsey Fathometer (see **524**), it is possible to measure with it the tide in offshore areas. To obtain results of acceptable accuracy, the sea should be relatively calm, the position for the observations should be selected where the bottom is known to be level, and the vessel should be anchored with a minimum length of chain.

Tide observations by this method are of value for determining the characteristics of the tide at a considerable distance from shore and in areas nearer shore where differences in range and time of tide are suspected. When such observations are correlated with simultaneous tide records at shore stations, the latter may be adapted for use in the reduction of offshore soundings. The observations to be of most value should be continuous over at least a 25-hour period, and a considerably longer continuous series is highly desirable. As a check on the accuracy of the results, repeat observations should be made during different periods at the same position.

For observing tides, echo soundings should be read at regular consecutive intervals of not less than 15 minutes, recorded on Form 277, Tides, and plotted on cross-section paper. Irregularities in recorded heights can then be eliminated by sketching a smooth curve from the plotted values. Both recorded and adjusted heights should be included in the data forwarded to the Washington Office. A report should accompany the record, giving the latitude and longitude of the observations, the condition of the sea (height of waves, swell, etc.), the depth of water, amount of chain used in anchoring, and an interpretation of results with an estimate of accuracy obtained. When a graphic recorder is used, the original *fathogram* should also be sent to the Office to aid in the interpretation of results.

Tide observations in offshore areas have been made with apparatus of European design operated from a ship at anchor or installed on the ocean bottom and marked with a buoy for future recovery. The principle of operation consists of the measurement of the change of pressure as the tide rises and falls.

A proposal has been made by the British that tides be measured by placing the transmitting and receiving unit of a recording echo-sounding instrument on the sea

bottom, directed vertically upward, to obtain an echo from the water surface, thus measuring the rise and fall of the tide.

### *1437. Tide Observations by Radio*

Tide observations, especially in flood-control work, are also obtained by means of an automatic gage that broadcasts the height of the tide by radio to the survey party.

## 144. Compass Deviations

For the accuracy of hydrographic surveys and the safety of the survey vessel it is essential that the errors of magnetic compasses be kept to a minimum and that their amounts be accurately known (see **4414** and **4415**).

Each survey ship and auxiliary vessel equipped with a magnetic compass shall be *swung* to determine the compass errors, which shall be compensated for, so far as practicable, at the following times:

(*a*) After any extensive lay-up period in port, before proceeding to sea.
(*b*) On the working ground at the beginning of each season's work.
(*c*) During the field season whenever there is evidence of an important change in the deviations.

The ship shall be swung and the compass compensated according to the instructions in Special Publication No. 96, Instructions for the Compensation of the Magnetic Compass. The results of the ship swing are recorded on Form 354, Observation of Compass Deviations, and computed on Form 355, Computation of Compass Deviations, and Form 356, Analysis of Compass Deviations.

The deviations of the magnetic compass used in hydrographic surveying shall be entered on page 1 of the first volume of the Sounding Records of each hydrographic survey and, if changed during the survey, the new values shall be entered in the appropriate volume, with the date of their applicability given (see **819*c***).

A deviation table on Form 261, containing the most recent values, shall be posted in the pilothouse or chartroom of every survey vessel.

## 145. Weather

A study of the meteorological conditions is of paramount importance, not only for the safety of the vessel, but also for efficient planning of the survey operations (see **1333**). For the safety of the vessel, the regular Government forecast will usually suffice. Major weather bulletins are issued daily via the United States Naval Radio Stations and many special local broadcasts are made by certain specified radio stations. Condensed data pertaining to the broadcasts are contained in chapter 1 of each United States Coast Pilot. Additional information on weather broadcasts will be found in the publications issued by the United States Weather Bureau, and in Hydrographic Office Publication No. 206, Radio Weather Aids to Navigation (1941).

### *1451. Transmission of Weather Reports*

Regular weather reports should not be sent from vessels of the Coast and Geodetic Survey unless specific arrangements have been made with the United States Weather Bureau. When engaged in offshore operations or when surveying in isolated localities, the Chief of Party shall ascertain from the Weather Bureau if regular reports are desired and, if so, he shall collaborate in furnishing them. Such reports should be

sent in the International Meteorological Code, a copy of which may be obtained by application to the Weather Bureau.

It is to be noted that it is obligatory for every master of a vessel to report any danger to navigation. This includes the reporting of tropical storms or other seriously bad weather which might endanger shipping.

### *1452. Storms at Sea*

When vessels are operating in areas where bad weather predominates, or where typhoons or hurricanes prevail during certain seasons, intense studies of these phenomena must be made by the survey personnel. Much valuable data on winds and cyclonic storms will be found in Chapters 21 and 22 of H. O. Publication No. 9, American Practical Navigator (Bowditch).

### *1453. Local Weather Conditions*

Meteorological conditions often seriously impede the progress of the survey. Few operations in a hydrographic survey can be conducted with efficiency and accuracy during stormy weather and much of the work requires exceptionally good weather. The Government weather forecasts deal with general conditions, but the conditions that must be considered in planning the day-to-day field operations are frequently local and it is only by long experience and a determined study of these, based on the general forecast and supplemented by personal observation, that full advantage can be taken of them.

Weather conditions vary from the almost perfect (encountered in certain tropical regions) to the consistently bad (prevalent along certain portions of the coast). Under the latter, which may consist of stormy weather or fog and haze, the execution of the work is a constant struggle, and the ability to predict the local weather is an asset to any survey party. Since the cloud forms and other meteorological characteristics that forerun certain changes in weather in one locality often precede widely differing weather in another locality, it is obvious that forecasting can be done only by one with considerable local experience.

There is a regularity about certain phases of local weather which, after a knowledge of it has been gained, may be used to advantage in planning the field work. For example, the diurnal change in temperature and pressure along the coasts results, in summer in particular, in a sea breeze which begins in the morning between 9 and 11 o'clock after the land warms, and dies away in the late afternoon, being then replaced by a land breeze which blows gently until morning. In the Tropics, this phenomenon is repeated with great regularity.

In some localities there is a dependable cycle of weather conditions during which a period of calm or exceptionally clear weather may be expected at the same regular position in the cycle. For example, along the southeastern coast of the United States, periods of stormy southeasterly weather are regularly followed by a north to northwesterly wind which blows offshore, accompanied by comparatively clear atmosphere. The trend of the coastline in the locality forms a lee, so that even during moderate winds, the sea is calm inshore and survey operations may be conducted there.

For certain phases of the field operations, exceptionally clear weather is required. This can only be predicted from a local knowledge of the area. It has been noted, for example, that along the southeastern coast of the United States periods of such weather

are accompanied by a pearly translucent appearance of the sky to seaward for a few degrees above the horizon.

When operating in an island area, it is frequently possible to find clear and comparatively calm weather on one side of an island or group of islands when there is fog or stormy weather on the other side.

Fog, haze, smoke, and other atmospheric conditions seriously interfere with most survey operations, and when these are prevalent, the few days of good weather which intervene must be taken advantage of to the fullest extent. A shift in the wind, or change in barometric pressure, is often accompanied by local clearing weather which cannot be foreseen from the Government weather broadcast.

When a survey vessel operates in an area of consistently bad weather, concerning which there is little information, a detailed report of the conditions found, and how best to take advantage of them, shall be made in a special report, in order that the information may be utilized by future survey parties operating in the same locality. (See **8584**.)

## 15. MISCELLANEOUS PROJECT OPERATIONS

### 151. Standard Time

Standard time shall be used in all hydrographic surveys, the hours being numbered consecutively from 0 (midnight) to 23 (11 p.m.). When applicable, the standard meridian used must always be noted. This is important in all records to be reduced for tide and in records of astronomic observations.

It is not necessary that the standard meridian used be that of the standard time zone in which the project is located. A party may keep its clocks set to daylight-saving time or any other time, if desired, but the standard meridian corresponding to the clock time must be noted. If the project is located in two standard time zones, one standard time shall be selected for use, and the standard meridian noted in the records.

### 152. Tide Predictions

A knowledge of the approximate tide is necessary in connection with almost all operations of a hydrographic survey party. This is essential for planning work that should be done at a certain stage of the tide. No party should ever be permitted to leave the ship or a shore base without these data. It is frequently sufficient to know the predicted times and heights of the high and low waters, a mental interpolation sufficing for intermediate values.

For some of the operations more exact values are necessary. When the hydrographic survey is of an area with a comparatively large range of tide or where the bottom is even, predicted tides must be used for the preliminary reduction of soundings for boat-sheet plotting. They are necessary also when determining the least depth on a shoal. These predictions may usually be obtained with sufficient accuracy from the Tide Tables (see **1521**), but in some instances a predicted tide curve may be needed and will be furnished by the Washington Office, upon request.

#### *1521. Predictions From Tide Tables*

When the Tide Tables are used, the procedure is as follows:

(1) From table 2 find the tide differences applicable to the area being surveyed. Apply these differences to the tide predictions for the reference station and obtain the corresponding times and heights of the high and low waters covering the period of the work.

(2) On cross-section paper, as illustrated in figure 4, plot the low- and high-water points $A$ and $E$ in accordance with the time and height coordinates.

(3) Divide the connecting line $AE$ into four equal parts at points $B$, $C$, and $D$.

(4) Take point $B'$ vertically below $B$ and point $D'$ vertically above $D$, at a distance equal to one-tenth of the range of tide.

(5) Draw an approximate sine curve through points $A$, $B'$, $C$, $D'$, and $E$. This curve will closely approximate the actual tide curve and the required data may be readily scaled from it.

On the tide curve thus constructed the points at which changes in reducers occur can then be marked (see **8224**). Thus, when the reducers are desired in integral feet,

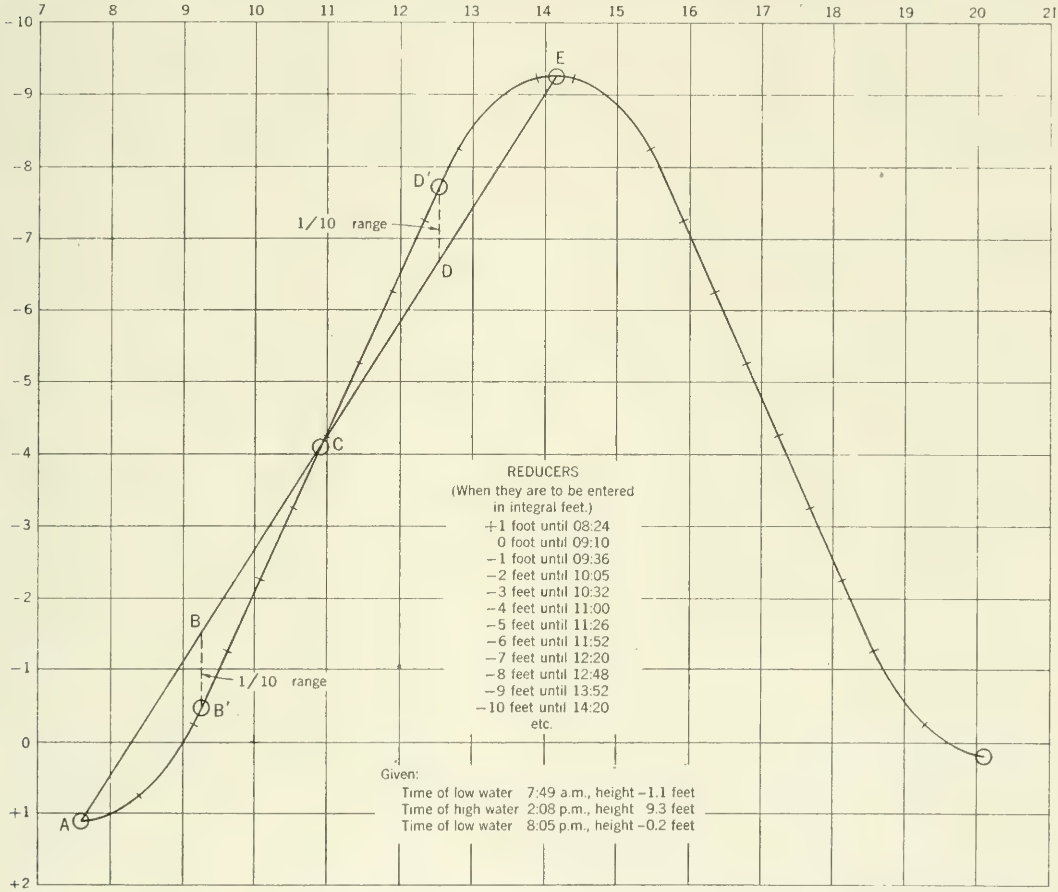


FIGURE 4.—Construction of predicted tide curve.

the curve should be marked at points 0.25 above each foot and the corresponding times noted. A tabulation of reducers and times of change can then be taken from the curve and furnished to each unit before starting each day's work.

### *1522. Predicted Tide Curve*

When a predicted tide curve for a reference station is furnished by the Washington Office, a time correction and range factor will usually be necessary to make the curve applicable to the project area. These corrections will generally be indicated on the curve by the Office.

The predicted tide curve furnished by the Washington Office is on a long roll of paper 6 inches in width. If it is to be used extensively it will be convenient to construct a small wooden box containing two spools, each of which can be turned by a crank. By these cranks the roll of paper can be wound from one spool to the other, passing over the flat top surface of the box where it is exposed to view between the two spools.

*a. Time correction.*—If the tides in the area sounded occur earlier or later than at the reference station, the original numbering of the hour marks must be decreased or increased, respectively, by a corresponding amount. The hour marks on the tide curve are usually not numbered, but the beginning of each day can be identified by a double downward jog in the datum line. With a time allowance of +1 hour this double jog will be taken as 1:00 to adapt the curve to the working ground, but if the time allowance is −1 hour the double jog will be taken as 23:00 of the preceding day.

*b. Range factor.*—The allowance for the difference in range can be most conveniently made by the use of an improvised scale, on a strip of celluloid or paper, representing the product of the original marigram scale by the reciprocal of the *ratio of the ranges*, as taken from the Tide Tables. Thus, if the marigram scale is 1/30 and the ratio of the ranges 0.8, then the improvised scale will be $1/30 \times 10/8 = 1/24$. The datum line of the marigram represents the mean sea level, which on the outer coast may be taken as practically the same as half-tide level. To obtain the heights of the tide at a given place, the improvised scale is placed on the marigram with its zero at a distance below the datum line equal to the depression of the plane of reference below mean sea level or half-tide level. For the Atlantic Coast, this depression is approximately the half range of tide at the working ground. For the Pacific Coast, it will be the half range of tide plus the diurnal low-water inequality. Where there have been previous tide observations in the locality, the relation of the plane of reference to half-tide level can usually be taken directly from the bench-mark data.

Where previous tide observations are not available, an approximate setting of the improvised scale on the datum line can be obtained by multiplying the ratio of the ranges for the working ground by the depression of the datum plane below mean sea level at the reference station. The depression can be found in the List of Reference Stations preceding the daily predictions in the Tide Tables. Thus, if the ratio of the ranges at Oakland (the working ground) is 1.2 and the plane of reference at San Francisco (the reference station) is 3.0 feet below mean sea level (from List of Reference Stations), then the setting of the scale on the datum line of the marigram would be 3.0 feet × 1.2 = 3.6 feet.

## 153. Magnetic Observations at Sea

Magnetic observations at sea with special instruments will ordinarily be taken on a nonmagnetic vessel or on a survey vessel by an observer especially trained for this work. When such observations are desired, special instructions will be issued for them.

Recent experiments have disclosed that, under the best conditions, a *ship swing* may be made in a nonmagnetic small boat which will give a reasonably accurate value of the magnetic variation. If practicable, the *swing* should be made where there is a depth of water of 50 fathoms or more so that the compass is not likely to be influenced by any local magnetic attraction in the ocean bottom.

The boat selected for this purpose should be as free as possible from magnetic material. Bronze fittings should be substituted for iron fittings where practicable,

as for example the iron oarlocks. Two wooden outriggers are constructed from 4- by 4-inch by 16-foot lumber and installed temporarily athwartship on the gunwales, one forward and one aft. To the four ends of the outriggers are hung four canvas sea anchors, each approximately 36 inches in diameter. The sea anchors should be suspended well below the surface of the water, so they will be beneath any wave motion, and be weighted by 16-pound sounding leads to ensure that the lines supporting them will be taut at all times. These sea anchors are for the purpose of minimizing any rolling motion of the boat.

The observations may be made on a ship standard magnetic compass, but a special spherical-type compass is preferable if available. The spherical glass top magnifies the compass card, which is equipped with a shadow pin of sufficient height to permit the magnetic bearings of the sun to be read directly, provided its altitude is not too great. The compass should be mounted on a stand in the center of the boat. No iron nails, bolts, or other magnetic metal should be within 4 feet of the compass.

The same method is used in swinging a small boat as in swinging ship (see **4415**). The man at the steering oar stands where he can see the compass and steadies the boat on each desired heading. A swing to the right on 24 headings is immediately followed by a similar swing to the left on the same headings, four observations on the sun being taken on each heading.

This method of making magnetic observations should be attempted only when the sea is comparatively calm. When the survey ship is engaged on offshore sounding lines it is frequently practicable to lower a boat party to make the observations, picking it up again on a return sounding line, with very little delay to the progress of the work. A complete set of such observations can be made in about 2 hours.

Azimuths may be obtained by observations from the boat, on the sun or on a distant land object whose position is accurately known, or from land by an observer at a known position. In the second case the position of the vessel or boat should be fixed at the time of each observation.

## 154. Survey Numbers

### *1541. Field Numbers*

For convenient reference during the season, each hydrographic sheet shall be assigned a field number. This field reference number shall be composed of the first two letters of the name of the survey vessel, followed by a 4- or 5-digit number, the last two digits of which represent the year, the third from the last representing the number of the sheet in the series, and the first one or two numbers representing the scale, any scale larger than 1:10,000 being indicated by a zero as the first digit. For example: Oc–8341 would designate the third 1:80,000 scale sheet initiated by the ship *Oceanographer* in 1941. The final two digits represent the calendar year in which the survey was initiated, or the number was assigned, and are not to be changed if the survey extends into the following calendar year.

For the same use each topographic sheet shall be designated by a capital letter assigned in alphabetical order during the season, a new series starting with "A" each season. The complete reference shall be composed of the first two letters of the name of the survey vessel, followed by the capital letter, followed by the last two digits of the year, all connected by hyphens. For example: Ex-B-41 would indicate the second topographic sheet initiated by the ship *Explorer* in 1941.

Prior to the assignment of registry numbers, the field designation shall be used to refer to a survey in all correspondence and reports relating to it, and on all applicable progress sketches and sheet layouts. The field number shall be shown in one or more places on the back of each sheet when it is forwarded to the Washington Office (see **3213** and **793**).

For surveys of the Philippine Islands, registry numbers are assigned by the Manila Office at the time a project is planned and there is, therefore, no need for the use of field numbers.

### *1542. Assignment of Registry Numbers*

Each season, as soon as it can be ascertained with reasonable certainty, the Chief of Party shall request from the Washington Office the assignment of registry numbers to the hydrographic and topographic surveys that will be completed during the current season. A registry number will then be assigned for each field number. Such a number consists now of four digits preceded by the capital letter H- or T- identifying it as a hydrographic or topographic survey. These numbers have no geographic or calendar significance. Numbers should not be requested for surveys which have been started, but of which there is some doubt as to their completion during the season.

Topographic surveys made on both sides of aluminum-mounted sheets should be definitely identified on the list requested, as each sheet is assigned one registry number, its two sides being identified by sub-*a* and -*b* letters. Topographic surveys made on Whatman's paper should also be identified on the list as they are assigned numbers from a different series than that used for aluminum-mounted sheets.

The request for registry numbers should be accompanied by a complete sheet layout diagram showing the field numbers, unless such layout has been shown on the monthly progress sketch. The diagram should be made in black ink so that photographic copies may be made.

### *1543. Use of Registry Numbers*

After a registry number is known, it shall be used in lieu of the field number in all correspondence, reports, etc. The registry number shall be clearly shown in one or more places on the back of the boat sheet and smooth sheet (see **3213** and **793**), when they are transmitted to the Washington Office. It shall likewise be shown in the appropriate space on every record relating to the survey. In all correspondence and in the text of all Descriptive Reports, etc., each reference to registered hydrographic and topographic surveys shall include the year of the survey in parentheses after the registry number, thus: H-6381(1939).

When hydrographic and topographic surveys are received and registered in the archives in the Washington Office, the registry number is stamped prominently on the back of each sheet in all four corners and is placed on the face of the sheet as part of the title of the survey. Infrequently, due to unforeseen circumstances, the registry number assigned to the field party is changed in the Office. In such cases, appropriate corrections will be made in all the records and reports pertaining to that survey.

## 155. Landmarks for Charts

A report on landmarks for charts on Form 567 is required from practically all Chiefs of Party. During the progress of the survey, each member of the party should note all objects which will serve for this purpose.

Landmarks on charts are for the aid of the mariner navigating the adjacent waters, and the objects recommended for this purpose should be selected with this fact in mind. They should be such as could be used for control objects by a hydrographic survey party, except that only the most prominent of these are of value.

The selection of objects should be made as the offshore water area is sounded, since from this viewpoint an adequate selection is relatively easy. When the selection is made by a survey party based on shore or engaged in land operations, extreme care is necessary in making a selection. Objects not visible from the water should seldom be reported; if practicable, an inspection should be made from the water area to determine the value of the objects reported. The report should state whether or not this inspection has been made.

The report on landmarks should cover the entire area surveyed during the season and should be based on an over-all study of the area. Form 567 should not be submitted for each hydrographic or topographic survey. Where there is a plethora of landmarks in any given area only those of special importance or prominence should be reported. By contrast, however, objects of lesser prominence may become important in an area where there is a paucity of landmarks. It is desirable that there be a proper distribution of landmarks reported rather than a concentration of a large number in a small area.

Usually landmarks important enough to be listed in the report will have been located by triangulation or topography during the progress of the survey. For landmarks not so located, in areas covered by the planimetric maps of this Bureau, it will usually be practicable to locate them with sufficient accuracy by reference measurements to identifiable detail on the maps. In one test of this method, seven landmarks were located which were subsequently located by triangulation. A comparison of the resulting positions gave an average difference of location of only 1½ meters, with the largest discrepancy 4 meters.

A report of landmarks to be deleted from the charts because no longer existent or not prominent is also important, and should be submitted on Form 567 at the end of the season. A systematic check should be made of the charted landmarks as the survey progresses.

Instructions for the preparation of Form 567 are given in **8534**.

### *1551. Objects for Use in Locating Aids to Navigation*

The personnel of United States Coast Guard tenders use the three-point fix method, wherever possible, to locate floating aids to navigation and to replace them on their stations. For their use in this work a special chart shall be prepared by each hydrographic party on which shall be shown the objects, natural or artificial, best suited for this purpose (see **8533**).

During the survey each floating aid to navigation shall be visited for the purpose of selecting by inspection the most suitable objects. These need not be restricted to landmarks recommended for charting; if there is an insufficiency of these in the most appropriate locations, they should be supplemented by less prominent objects, visible from the respective aids, and located specifically for this purpose. Permanent objects not likely to be destroyed or moved shall be selected. The use of beacons, range marks, targets, etc., should be avoided. If three suitable objects cannot be seen, two objects should be noted, if practicable, to which bearings can be measured.

## 156. Statistical and Cost Data

Each Chief of Party is required by the Regulations to submit certain statistical and cost data relative to his field work. Among the forms required for this purpose are: Form 20a, Monthly Report and Journal of Field Party; Form 21, Statistics, Cost, and Summary of Field Work, and Form 615, Summary of Monthly Reports and Journals of Field Party and Cost Apportionment, the two latter required at the end of each season; and Form M-1133-5, Annual Statistical Report, which is submitted at the end of the fiscal year. (See also **851**.)

For use in preparing the required seasonal and annual reports Form 20a should be complete and accurate; the cost data should correspond with those on Form 474, Statements of Allotment Balances, and the sums to date of the entries for each fiscal year should agree with the total encumbrances or total payments appearing on the Statements of Allotment Balances for the various appropriations.

As a convenience in the preparation of these and other forms, each Chief of Party should have memoranda kept of the various items involved as the work progresses, as this will save extensive examination of the records and will avoid a reliance on memory at the end of the season. Planning of the field operations with the preparation of these reports in mind will aid in their compilation.

A commendable practice is the inclusion in the season's report of a chronology of the important events occurring during the season. Memoranda kept of these as they occur will greatly facilitate the preparation of this report.

## 157. Current Surveys

A knowledge of tidal and other currents is of great importance to the mariner, and current observations are required upon which to base published current predictions. Systematic current surveys are usually made by survey parties especially organized and instructed for this work, and long series of current observations are made from time to time by the personnel of lightships through the cooperation of the United States Coast Guard.

In areas where currents of importance to navigation occur and detailed current surveys have not been made, current observations should be obtained by the hydrographic party. Especially valuable are current data obtained in calm weather from survey vessels at offshore anchorages. The current should be measured with current pole and line in accordance with the procedure outlined in Special Publication No. 215, Manual of Current Observations. To be of material value the observations should cover a period of not less than 25 consecutive hours, although shorter series, such as overnight observations, will have some value when the longer series cannot be secured.

## 158. Navigation and Seamanship

A knowledge of and experience in the technique of surveying is of little practical value in hydrographic surveying unless supplemented by a proficiency in navigation and seamanship; in fact, skill in many phases of hydrographic surveying can scarcely be attained, or is almost useless, without an accompanying ability in navigation and seamanship. The operation of sounding from a vessel underway frequently requires navigation of the highest order, and many of the conditions which are encountered almost daily by the hydrographer are met by the average mariner only in emergencies. A knowledge of how to navigate and handle his vessel under all conditions and of the

proper use of lines, anchoring gear, and similar equipment is especially essential for the hydrographer.

Every officer engaged in hydrographic surveying should endeavor to perfect himself in the theory and practice of navigation. The Chief of Party should encourage his officers in this and provide them with every reasonable opportunity to gain experience in its actual application. Seamanship should be studied and practiced by the officers and the crew, to whom should be made available some of the excellent standard treatises on the subject. (See **9532**.)

The natural environment of a ship is sea water. It has been said that "any well-found, shipshape, modern, seagoing steamer or motorship is safe so long as she has plenty of water under her keel, plenty of fuel in her bunkers, a competent navigator on her bridge, and a well-trained and disciplined crew at their various stations." The only real danger in a modern vessel at sea is the *personal element* and one of the worst phases of this factor is the almost universal human tendency to become careless in matters which have become routine. In the very nature of his work, the hydrographer is frequently required to take his vessel into unsurveyed and dangerous waters, but familiarity with such conditions should not lull him into a contempt for the danger involved. Only a continued alertness will keep sufficient "water under her keel."

The study and practice of navigation and seamanship will provide a "competent navigator" on the ship's bridge and proper training and leadership will provide "a well-trained and disciplined crew."

### *1581. Safety of Survey Ship*

The Commanding Officer of a survey ship has a grave responsibility; he is personally responsible for the accomplishments of the party, but he is also responsible for the lives and safety of his officers and crew and for the safety of an expensive survey ship.

The nature of hydrographic surveying requires that more risk be taken at times than would be necessary in commercial navigation; this is especially true when operating in an unknown or previously unsurveyed area. To prosecute such work expeditiously it is necessary to run some risks that would otherwise be considered foolhardy. In such cases the Commanding Officer must exercise the nicest discrimination, but both he and his officers must beware of overconfidence.

In surveying an area where a known danger exists, or where one has been reported or is suspected of existing, the Commanding Officer is negligent in his duty if he fails to take certain definite precautions. He must combat a false sense of security which tends to be built up from years of surveying in dangerous waters. Because of the wide variety of possible dangers and conditions, no all-inclusive rules of safety can be drawn. The following general rules should, however, always be followed during a hydrographic survey when approaching, or surveying in the vicinity of, a known or suspected shoal, which may endanger the vessel; the application in each specific case depending finally on the judgment of the Commanding Officer:

(1) If practicable, the dangerous area shall be first surveyed from a launch to find and locate the danger and to survey an area around it with which a junction can be made in safety from the survey ship.

(2) The Commanding Officer, before approaching the area, shall make a careful study of *all* available data.

(3) The Commanding Officer shall be on the bridge, and shall assume charge of the navigation of the ship.

(4) The survey ship shall be slowed down.

(5) An officer shall be on the lookout in addition to any members of the crew.

(6) It must not be assumed that the ship will pass at a safe distance from a danger just because the ship's position plots at what seems to be a safe distance from the charted or plotted position of a shoal. Charted positions of shoals are occasionally inaccurate from having been charted from reports or inadequate data.

(7) When approaching a possible danger at the time of relieving the watch, the officer-in-charge of the bridge shall remain in charge until the danger has been passed, or until the relieving officer has familiarized himself thoroughly with the situation and feels entirely competent to assume charge. Any subordinates from the first watch whose services are deemed desirable shall likewise be retained.

(8) Refer also to **361**.

### *1582. Small-Boat Landings*

There is perhaps no one phase of seamanship so essential in hydrographic surveying as competency in handling small boats and making landings on exposed coasts. Most hydrographic surveys consist of operations along the coastal area where the sea meets the shore, and where the greatest danger lies. The very nature of the operations requires the use of small boats and repeated landings on the shore. An important feature of the training of new members of a crew at the beginning of each field season is to familiarize them with these duties and to provide every opportunity for them to acquire practice.

Officers and a crew who are experienced lifeboatmen and seamen are essential in hydrographic surveying, but it must not be assumed that one who is an otherwise competent seaman has the necessary knowledge and experience to make small-boat landings under dangerous conditions. This is an art in itself, requiring a special knowledge and skill only acquired by practical experience and which many seafaring men never have occasion to practice. When undertaken by the inexperienced, the danger involved can scarcely be overestimated.

The subject is adequately treated, insofar as practicable in text, in many treatises on seamanship, and these should be studied thoroughly and reviewed at the start of each field season (see **9532**). The rules published by the Royal National Lifeboat Institution on the subject are very helpful. Some valuable comments on coast landings are included on page 2, Alaska Coast Pilot, Part II. An almost infinite variety of conditions may be encountered, and the method adopted must vary to meet them successfully. This Manual can only emphasize the importance of the following in connection with small-boat landings under difficult conditions:

Use only experienced personnel.

Conditions never appear as dangerous from seaward as they really are.

Always use a steering oar, never a rudder.

Keep the boat under control at all times.

The outermost of a series of breakers is much the heaviest.

In a strange locality, lie-to outside the breakers to study the particular conditions before attempting a landing.

The one great danger, when running before a broken sea, is that of broaching-to.

A number of heavy swells are often followed by a short and comparatively mild interval.

Launching a boat through breakers is a more difficult and exhausting operation, though not necessarily a more dangerous one, than making a landing under similar conditions.

An entirely different technique is required on a steep rocky shore from that required on a gently sloping sand beach.

### *1583. Flags*

Flags shall be displayed by vessels of the Bureau as follows: The national ensign at the flagstaff and the Union Jack at the jack staff in port or at anchor from 8 a. m. to sunset; the national ensign at the gaff at sea during daylight when in sight of land or other vessels; and the service flag at the fore truck when the national ensign is displayed. The commission pennant shall be flown at the main truck at all times.

### *1584. International Code Flags*

A complete set of International Code flags shall be carried for navigational purposes, being displayed as the occasions require.

A card illustrating the various flags shall be kept in the pilothouse in a convenient location.

Ships and auxiliary vessels engaged in hydrographic surveying underway in the daytime should display suitable International Code signals in areas where there may be considerable foreign steamer traffic. The appropriate International Code signals are:

"HD," signifying "I am engaged in submarine work, you should keep clear of me."
"HF," signifying "I (we) have a sweep out, you should keep clear of it."
"ONA," signifying the same as "HD."

In addition to the above signals, the code flags most frequently used by ships of the Coast and Geodetic Survey are the red flag to indicate that explosives or highly inflammable fuels are being loaded, and those composing the groups used in recalling launch and shore parties.

### *1585. Signals for Use During Hydrographic Surveying*

The special signals prescribed for daytime use to indicate that a vessel underway is engaged in hydrographic surveying are three shapes, not less than 2 feet in diameter, carried in a vertical line, not less than 6 feet apart, where they can best be seen; the highest and lowest shall be globular in shape and green in color, and the middle one diamond in shape and white in color.

Ships and auxiliary vessels of the Coast and Geodetic Survey shall carry the above prescribed marks at all times while actually engaged in hydrographic surveying underway, including wire-drag operations. Launches and other boats shall carry the prescribed marks when necessary.

By night a survey vessel of the Coast and Geodetic Survey, engaged in hydrographic surveying underway, shall carry the regular lights prescribed by THE RULES OF THE ROAD.

A vessel of the Coast and Geodetic Survey, engaged in survey operations at anchor in a fairway, shall display from the mast during the daytime two black balls in a vertical line and 6 feet apart. At night two red lights shall be displayed in the same manner. In the case of a small vessel the distance between the balls and between the lights may be reduced to 3 feet if necessary. A flare-up light shall be kept at hand and shown if necessary to attract attention in addition to the two red lights prescribed.

It must be emphasized that the display of the prescribed shapes or the flag code signals serves only to indicate the nature of the operations and in no way gives the survey vessel the right-of-way over other vessels nor relieves it from a strict observance of the rules for the prevention of collisions of vessels.

When it is apparent that an approaching vessel does not heed signals displayed by the survey vessel, the "danger signal" (not less than four short and rapid blasts of the whistle) should be sounded by the survey vessel.

## 159. Coast Pilot Reports

All hydrographic parties shall collect coast pilot information and furnish at the end of each season a special report on this subject for use in the revision of the Coast Pilot of the area. This report should include information obtained while en route to and from the project area as well as that gathered on the working ground. It should be a compilation made from the notes and memoranda kept by each hydrographic

unit and the survey ship, all gathered into one comprehensive report (see **385**). The report should be submitted in duplicate, the information to be contained therein and the manner in which it should be furnished being described in **912** and **916**. In all cases where the information in the published Coast Pilots is found to be accurate and adequate, a statement to this effect should be included in the report.

Such data should not be made a part of the Descriptive Report or if they are included therein they should be repeated in the special coast pilot report.

Important information and especially anything affecting the safety of navigation should be forwarded to the Washington Office at once and dangers to navigation discovered should be reported by radio.

### *1591. Photographs*

Photographs of field activities, personnel, and equipment, particularly when they illustrate actual survey operations, are of considerable value. Chiefs of Party are directed to have such photographs taken whenever practicable and forwarded to the Washington Office. Photographs are particularly needed illustrating new equipment, new types of apparatus, and the various kinds of signals and buoys. Photographs are also needed illustrating new techniques of actual field operations.

Negatives are preferable to prints since they afford better reproduction. Photographs should be comparatively large or be taken with a camera that will permit subsequent enlargement. An effort should be made to obtain sharp distinct outlines and decided contrasts. A photograph of a piece of equipment or other inanimate object should include a person standing nearby or an object of known size to show relative size.

Photographs intended for illustrations in Coast Pilots should be taken from a position where the view would likely be most useful to the mariner, such as when making a landfall. In a region where the coast may be closely approached with safety, photographs of distinctive features which can be identified during low visibility are especially useful. In this case they should be taken close to the feature. The title of a photograph intended for a coast pilot illustration must always include a statement of the distance of the feature and the direction toward which the camera was pointed.

The negatives or duplicate prints of illustrations for a season's or special report should be submitted separately so that the report will not be mutilated by removing the photographs for registration and filing.

A photograph is useless unless it is accompanied by certain descriptive and historical data. Each photograph or negative should be accompanied by Form 623A, Photographic History, on which information should be furnished for items 3 to 8, inclusive, and item 13. The descriptive title should be sufficiently comprehensive to leave no doubt regarding any feature of the photograph. After a negative has been registered, prints may be ordered by reference to the registry number.

## 16. GEOGRAPHIC NAMES

Correct geographic names are essential on every nautical chart. In well-populated areas many geographic names are soon well established in local usage because of the need people have for referring to the features in their vicinity. But even in unpopulated regions distinctive names for the more important geographic features are necessary for the intelligent use of charts and Coast Pilots. It is distinctly annoying and conducive to error to have to use latitudes and longitudes or long descriptive phrases to refer to geographic features.

### 161. Geographic Names on the Hydrographic Survey

The principal sources of the charted geographic names are the hydrographic and topographic surveys made by the Bureau. For the project area the geographic names already charted should be verified, and all additional names well established in local usage should be sought out. The hydrographic and topographic surveys are source material; geographic names should not be merely copied from other maps and charts—the field party should verify, if practicable, whether or not they are in undisputed local usage, before placing them on the sheets.

The hydrographic surveys should be the authority for all geographic names seaward from the high-water line, including the names of all water features such as channels, sloughs, rivers, inlets; and those of the reefs, rocks, banks, and shoals therein; and all small islands and the names of geographic features thereon. Only a few geographic names on the mainland need be included and these principally for reference purposes.

Topographic surveys, planetable and air photographic, should be the authority for all geographic names inshore from the high-water line, including the names of all land features; and in addition the names of lakes, small streams, rivers, and sloughs which are not sounded during the hydrographic survey.

It is almost impossible to have too many authentic geographic names on an original survey sheet, even though they may be far too numerous to be included on the charts of the area. The sheets will serve as source material and may be used as the authority for purposes other than charting.

Geographic names should not be inked on hydrographic or topographic survey sheets by the field party. They should be lettered in pencil and should refer unmistakably to the features named, but only after verification in the Washington Office will they be inked. (See **787**.)

### 162. Investigation of Geographic Names

It is particularly important that geographic names on the charts be correct not only as to name, but also as to spelling and application. No other feature on a chart or map is so easily verified by the user. Errors in geographic names are an indication of carelessness which soon reflects on the accuracy of the other charted data.

Field parties should not merely copy geographic names from current editions of the charts or other maps onto their hydrographic sheets. Charted names and those in the Coast Pilots should be checked against local usage. If a name is well established through long use on maps and charts and is appropriate it should be adhered to even though found to differ from local usage, especially if the feature is of more importance to navigation than it is to the inhabitants, or if the local name is an awkward or difficult one.

Where published names differ from local usage the hydrographer should ascertain how well established the local name is and, if possible, the origin of it. Dual names for the same feature lead to confusion and inconvenience and such cases are referred to the United States Board on Geographical Names for decision. A rather complete statement is required in each case and the sources from which the local name was obtained must be stated. (See **1671**.)

Map sources which are easily accessible to the hydrographer should be consulted for geographic names, but an exhaustive search for such material is not required. The standard quadrangle maps of the United States Geological Survey should be consulted

as well as any authentic local maps. Copies of the latter, if obtainable, should be forwarded to the Washington Office with the special report on geographic names (see **163**).

For names not found on published maps and charts, well-established local usage is the best and practically only authority. It is sometimes difficult, however, to ascertain whether or not a name is well established. Markers placed by an official agency such as a State highway department can usually be accepted as reliable evidence. Judgment is necessary in determining the reliability of persons questioned about names. Only those who have been long established in a locality should be accepted as authorities; those whose business has an intimate connection with the land should be consulted about names of topographic features, but only those living near or who have interests connected with the water should be consulted about names of hydrographic features. Newcomers in a locality may either not know or be indifferent about giving correct information, while others may intentionally mislead the inquirer for personal reasons.

The correct spelling of a geographic name must be ascertained. This is almost as important as knowing what the name is. Many common proper names may be correctly spelled in two or more ways; for example, Jouett and Jewett, Anderson and Andersen, Paynes and Paines. The pronunciation of a name, no matter how common it seems, cannot be trusted as a guide to the spelling; for example, Reaves Point on Cape Fear River is *not* Reeves Point, Jourdan River in Mississippi is *not* Jordan River, and Centers Point in Maine is *not* Senters Point. Well-established local usage can generally be accepted for the correct spelling of a new name, although it must be accepted with reservation for names that have historic background, particularly if the language of the present inhabitants differs from that of the original settlers. If the only authority for the spelling is local inhabitants, care must be taken to impress on them the importance of this feature. The spelling of new names may often be settled authoritatively by reference to legal documents.

Where names on federal maps and charts are found to be in disagreement or to be in disagreement with local usage a rather complete report of the facts is required. Many such cases may be traced to careless spelling. There was a time when comparatively little attention was given to the spelling of names, and during the settlement and early development of the country the spelling of even the commonest words was unsettled and capricious. Even today the spelling of the names of some of the prominent citizens of that period is still in dispute because they themselves signed their own names variously to different documents. The spelling of foreign and Indian names which have been applied to geographic features is often particularly confused.

A geographic name is usually applied to some particular feature which has identity like an individual. If the feature should cease to exist that name becomes meaningless and should be deleted from the charts. The practice of transferring a geographic name from one feature which has ceased to exist to another similar feature in the locality leads only to confusion and should be abolished. A typical example is where a previous inlet through a barrier beach has been closed permanently and another similar inlet breaks through a few miles away. However, this objection does not apply to an inlet or point of land that has migrated from its original position.

Errors in geographic names may occur because the name was incorrectly applied to a feature by the surveyor. It may appear on a map or chart as referring to one feature whereas as used locally it applies to a different feature in the immediate vicinity.

## 163. Special Report on Geographic Names

When practicable, the field party should submit a special report on geographic names to cover the entire project area, or several reports to cover it in parts, irrespective of the limits of the individual survey sheets. The report should contain all of the information resulting from the field party's investigation, relative to the names, arranged in a convenient reference form.

This method of submitting the data is by far the most satisfactory one when the hydrographic survey has been preceded by an air photographic survey, and it may be the most convenient method of reporting such information when the hydrographic survey is preceded by contemporary planetable surveys.

Usually in connection with the geographic names of a project area a comparatively large number of local persons are consulted and sometimes a large number of maps of the area are compared. A convenient way of reporting the results is to list the names of all of the consultees with their addresses, numbering each consultee so that easy reference may be made under each geographic name. A similar method may be used to report the maps and charts consulted by referring to each one by a letter of the alphabet.

Information regarding each name should be reported in a short concise paragraph, which should include the extent of the local usage, a discussion of any variations in spelling or application, the origin of the name and the date when it was first applied to the feature, if known. If the name is a descriptive one, a statement should be included as to its appropriateness. References to local usage as evidenced by posted signs, local maps, or in local writings, should be included.

In reporting local usage the hydrographer should be extremely careful to report the name in form and spelling exactly as used. This is particularly important when the possessive case is involved. It is the duty of the hydrographer to report the facts as he finds them, irrespective of any of the guiding principles of the Board on Geographical Names or preference on the part of the hydrographer or the Washington Office.

When a geographic name is pronounced locally in a way not apparent from the spelling, a phonetic explanation of the pronunciation should be included.

In addition to the above information the special report should contain recommendations for cases where local usage disagrees with the published charts of the Bureau (see **1631**). Charted names, which are found to agree with undisputed local usage and with other federal maps, should be listed and a statement made to this effect.

When no special report has been furnished, all of the above information required for geographic names should be reported in the Descriptive Report (see **164** and **165**).

A number of examples are given in **166** illustrative of the information which is desired relative to geographic names.

### *1631. Recommendations When Usage Disagrees*

When a charted name differs from that on other federal maps or from well-established local usage, at least three local authorities should be consulted. The hydrographer should make a recommendation as to which name in his opinion should be approved for charting. The recommendation should be based on how thoroughly the name appears to be established in local usage, on how important the feature is to navigation, on which name has the most individuality, and whether or not persons navigating in the area may use the charted name even if it differs from local usage.

The information should be complete enough so that the case can be submitted to

the Board on Geographical Names without further local inquiry by the Washington Office.

### 164. Assignment of New Names

In an unpopulated area which is being thoroughly surveyed for the first time on a large scale, names may be needed for previously unnamed features. When such features, in the opinion of the hydrographer, are important to navigation and will need to be referred to by navigators, in the Coast Pilots, or elsewhere, he should list them in the Descriptive Report, recommending suitable names (see **165**).

So far as practicable, names of the type already in use in the area and that have some historic, incidental, or descriptive significance should be selected. Names with a historic significance are preferable and a little research will often disclose satisfactory names connected with the history or traditions of the place, some characteristic of its inhabitants, or some outstanding happening in the vicinity. Descriptive names are generally unsatisfactory because most of them have been used repeatedly and their assignment to new features only adds to the confusion instead of providing names which identify as intended. Such names as Grassy Point, Round Island, Green Island, Mirror Lake, and many other similar names are in such frequent use that they provide no useful identification. When the form or character of the feature is so unusual that a certain descriptive name identifies it beyond doubt then that name should be recommended.

The correct generic term should likewise be recommended for the feature. Generic terms are applied differently in different regions and predominant local usage in this respect should be followed. In **168** definitions are given of a number of water features and some guiding rules for other features. For shoals and submarine features the rules should be followed for all new recommended names; for all other features they should be followed where there is no conflicting predominant local usage.

The recommended names should conform so far as practicable to the guiding principles of the Board on Geographical Names (see **1671**). All recommendations will be reviewed in the Washington Office and when considered inappropriate others will be substituted before the cases are submitted to the Board for decision.

### 165. List of Geographic Names in Descriptive Report

In addition to any other report or reports on geographic names (see **163**), each Descriptive Report shall contain an alphabetical list of all of the geographic names lettered in pencil on the sheet when forwarded to the Washington Office (see **8433**). If a special report covering all of these names has been or will be submitted, the information should not be duplicated in the Descriptive Report, but the latter should contain a reference to the special report as the authority. The Descriptive Report should supplement the special report if new facts have been discovered relative to any of the names previously reported on. When the alphabetical list contains geographic names which were not reported in the special report, the Descriptive Report should contain all of the information available relative to them.

Besides the above, the Descriptive Report should contain the hydrographer's recommendations for names for important previously unnamed features (see **164**).

## 166. EXAMPLES OF GEOGRAPHIC NAME INFORMATION

For the guidance of the hydrographer, the following examples illustrate the type of information which should be contained in the special report on geographic names required in **163**:

ARROWHEAD POINT—A descriptive name, in undisputed local usage. An official signpost, erected by the State highway department, bears this name and identifies the point. The name is derived from the shape of the point which resembles an arrowhead.

ATSENA OTIE (KEY)—In undisputed local usage. The name has appeared on various maps and surveys in the following varied forms: Atsenaotie, Atseniota Key, Ate Senotia, Otcena Otee, Atcena Otie. The name is so well known locally that local residents never realized there was any doubt about the spelling. It appears, spelled as above, on the local county tax rolls, first in 1874. A local newspaper, The Cedar Key Commercial, in September 1891, contained this statement: "Ferry boat *Col. Cottrell* will make regular trips between the island and Atsena Otie." A local resident possesses a picture post card, showing the pencil mill on the key in 1889, which contains this spelling.

At one time there were perhaps 1,000 people living on the key, but at present it is completely deserted.

According to local information the name is of Indian origin and the "Otie" may mean island or key. Locally the key is generally referred to simply as "Atsena Otie," without any additional generic term. The addition of the term *Key* is recommended, however, since its topography resembles other keys in the vicinity.

The present charted name of Depot Key is unknown locally.

BISHOP'S POINT—In undisputed local usage. The point was named after an early settler, now deceased. No local usage could be found for the name Wry Key, appearing on T-423 (1852–4), nor for Rye Key, appearing on the United States Land Office map, approved by the Surveyor-General in 1851. The name Bishop Point is recommended.

CROSS MOUNTAIN—A 4,000-foot peak near the north shore of the inner end of Silver Bay. The name is in undisputed local usage and is derived from the fact that snow, collected in deep ravines high up near the summit, appears as a large foreshortened cross. This snow cross is plainly visible practically all summer. Attention is directed to the fact that this name, Cross Mountain, is erroneously applied to an adjacent mountain on the charts of the area.

HODGES ISLAND—In undisputed local usage. Several generations of the Hodges family have lived and are buried on the island. Note that the final "s" is a part of the family name and not a possessive. One local resident states that the island was at one time known as Hickory Island.

MILL COVE—In undisputed local usage. The name is derived from an old tide mill which operated in this cove. Some maps show this name applied erroneously to another cove, but, according to all local residents consulted, it is correctly applied on T-4873 (1934).

MILL POND—In undisputed local usage. Histories state that "Here stood the corn mill and saw mill, erected probably in 1643 or 1644." Although this common name is used to excess throughout the country, its retention for this feature is nevertheless justified and recommended.

MT. HOPE—A charted name. No local resident could be found who was familiar with this name, nor is there apparently any local name for the feature. Because of the insignificance of the feature, the deletion of the name is recommended.

PATCH'S POND—A local name verified by three persons living in the vicinity and by the town engineer. The name is derived from the Patch Ice Company, which cut ice on the pond for many years. This pond is erroneously named Echo Lake on some maps. An earlier name was Flat Ledge Pond from the flat rocky ledge projecting from the shore out into the center of the pond.

SQUAW ROCK—A descriptive name, in undisputed local usage. It applies to a rock overhanging the shoreline and is derived from the fact that the rock resembles an Indian squaw.

WHITE MAN'S POINT—The Indian name for this point is unpronounceable and the spelling of the Indian name could not be ascertained. It is well established, however, that the translation of the Indian name is as given above. The name is no doubt derived from the fact that John Muir and his party camped on this point in the summer of 1890.

## 167. UNITED STATES BOARD ON GEOGRAPHICAL NAMES

The United States Board on Geographical Names was established by Executive order in 1890 (as the U. S. Geographic Board) to establish uniform usage throughout the Federal Government as to geographic nomenclature and orthography, particularly on federal maps and charts, and to decide unsettled questions concerning geographic names. Through several Executive orders the duties and authority of the Board have been changed, expanded, and more clearly defined, but essentially they are as originally defined.

The jurisdiction of the Board includes practically all disagreements concerning geographic names in which federal publications are involved. Its duties include decisions in cases of disputed geographic nomenclature, and in disputed spellings and applications of geographic names; the determination, change, and fixing of place names within the United States and its insular possessions; and the review of all newly assigned geographic names hereafter suggested for use in federal publications.

The decisions of the Board relative to geographic names are final so far as the Federal Government is concerned and are to be accepted as the standard authority.

### *1671. Decisions of the Board*

The full Board is composed of a number of federal employees representing the principal map and chart making agencies and a few representatives of nonfederal institutions.[1]

The decisions of the Board are made by an executive committee of three members whose actions are from time to time reviewed by the entire Board. The decisions are made available in mimeograph form to the persons principally interested soon after they have been made. The decisions made each fiscal year are published in leaflet form, and at long intervals all of the decisions of the Board since its establishment are published complete in one consecutive alphabetical list. The sixth report of the Board, published in 1932, is the latest complete report.

In general, the Board renders decisions only for cases which are submitted to it by the various federal agencies. The cases fall into three major classifications: first, where differences exist in name, spelling, or application on federal charts, maps, and publications; second, names for which established local usage is found to differ from federal usage; and third, assigned names recommended by a federal agency for heretofore unnamed features.

Each case involving a name is reported separately on a form to the Board, with all the information which the agency has available relative to the various usages found on maps and locally.

Many of the early decisions of the Board were rather routine—attention was mainly on variations in spelling, local usage was often not determined, and definitions were incomplete or indefinite—the tendency was to base decisions solely on the information furnished by the agency submitting the case. In recent years each case has been thoroughly investigated by the Board before a decision has been made. A thorough examination of past and present map usage is made, with special emphasis placed on federal map usage. If it has not been done by the submitting agency, the Board also solicits information from local residents who are most likely to be familiar with the facts. Formerly only the proper names were considered by the Board, but current decisions include the generic terms as well.

The Board follows certain guiding principles, which are not to be considered rules and from which it departs whenever it deems it advisable to do so. The following are some of the more important principles:

Euphonious and suitable names of foreign or Indian origin should be retained.

The excessive duplication of extremely common names, especially within one State, should be avoided.

Newly *assigned* names in honor of living persons are not approved.

Long and clumsily constructed names and names composed of two or more words are to be avoided. If a two-word name is essential, consideration is given to combining the two words into one.

Only one name should be applied to a stream throughout its entire length and the name should generally follow up its longest branch.

Where practicable, independent names should be given to the branches of a river—such names as East Fork and North Prong being avoided if possible—unless there is thoroughly established usage to the contrary.

The spelling and pronunciation which is in undisputed local usage should generally be adopted.

The possessive form should be avoided when it can be done without destroying the euphony of the name or changing its meaning. When the possessive "s" is retained the apostrophe is invariably omitted.

Where two or more names for the same feature appear to be equally established in local use, that which is most appropriate, euphonious, and older should be adopted.

There is some misconception regarding the application of a few of the principles. The restriction against naming features in honor of living persons is applicable only in the case of names which are newly assigned to previously unnamed features; the principle does not apply where names of living persons have become established as geographic names either through local or map usage. A geographic name in undisputed

[1] The Board on Geographical Names was reorganized and its staff and the scope of its functions were vastly enlarged in 1943. Its activities are under the Secretary of the Interior, and the Board as described in the text serves in an advisory capacity.

local usage for a feature previously unnamed on maps and charts is invariably approved without change; exceptions are when it is in the possessive form, indecent, objectionably inappropriate, and sometimes to restore an original spelling or a name with a historic background.

### *1672. Cases That Should Be Submitted to the Board*

Most geographic names may be used without being submitted to the Board on Geographical Names for a decision. Among these are the following, when they are not known to be in disagreement or in conflict with the principles adopted by the Board:

Names used on federal maps and charts published since 1920.

Names in undisputed local usage.

Names which have been "provisionally adopted" by the Board. (Baker's Geographic Dictionary of Alaska, Special Report on Geographic Names in the Philippine Islands published in 1901, and the Atlas of the Philippine Islands published in 1900, have been provisionally adopted.)

Official names of post offices appearing in the United States Postal Guide.

Names of structural features such as highways, bridges, and lighthouses.

Names in undisputed usage except for errors that are acknowledged as such, or are obviously typographical or accidental.

The following classes of names are to be submitted to the Board for a decision:

All new names recommended for previously unnamed features.

New names for previously named features and old names that are to be applied to features differing from the original ones.

Names for which there is an existing decision of the Board which appears to be incorrect or inadequate from latest information.

Names whose usages differ in federal or other publications, or whose local usage differs from published usage.

Names of towns and villages which differ from the names of the post offices or railroad stations located therein.

Names of *places* (cities, towns, villages, and settlements) which are duplicated within the same State.

Although not obligatory, it is generally desirable to submit the following types of cases to the Board for a decision:

Names of natural features which are likely to cause confusion through duplication.

Names for which there are existing decisions of the Board concerning which important new evidence has been brought forth or which it is believed might be revised if reconsidered.

Names for which there are existing decisions or names in undisputed use that are not spelled in accordance with their derivation or that are objectionable because they are awkward, misleading, or difficult to spell or pronounce.

Field survey parties are not to submit requests for decisions on geographic names direct to the Board on Geographical Names. All such requests are prepared in the Washington Office after the survey sheets and reports have been received and the geographic names have been reviewed.

## 168. Terminology for Submarine Relief

The following terminology should be used in referring to unnamed features that conform with the definitions, or when recommending new names for previously unnamed features. The definitions are intended to standardize usage in surveying and charting and have no legal significance. The features defined have been broadly divided into primary and secondary features. The primary features are, in general, major deep-sea or continental marginal features of considerable magnitude, the terms for which have attained international usage in recent years. The secondary features

generally comprise features of specific navigational importance as well as a few coastal and inland features, the terms for which heretofore have been used in a loose, confusing manner. The common terms referring to embayments and streams are often used locally with specific meaning applicable only in that region. From the standpoint of regional uniformity, it is often advisable in specific instances to follow such local or regional usage.

### *1681. Primary Features*

*a.* Marginal continental features:

BANK.—A detached, broad, and relatively shallow area on the continental shelf or in greater depths, not constituting a danger to navigation in itself, but from which may rise a reef, shoal, or other secondary feature, which is a danger to navigation. (See Bank in **1682.**)

CONTINENTAL SHELF.—The zone of the submerged continental margin from the coast offshore to the continental slope (in depths of about 100 fathoms).

CONTINENTAL SLOPE.—The declivity from the offshore border of the continental shelf at depths of approximately 100 fathoms to oceanic depths. It is characterized by a marked increase in gradient.

INSULAR SHELF.—The zone of the submerged margin of an island or group of islands from their coasts offshore to the insular slope (in depths of 50 to 100 fathoms).

INSULAR SLOPE.—The declivity from the offshore border of the insular shelf at depths of 50 to 100 fathoms to oceanic depths. It is characterized by a marked increase in gradient.

*b.* Deep-sea depressions:

BASIN.—A large submarine depression of a general circular, elliptical, or oval shape.

DEEP.—The well-defined deepest area in a submarine depression.

DEPRESSION.—A general term signifying any depressed or lower area in the ocean floor.

DEPTH.—The maximum sounding measured in a deep.

FOREDEEP.—A deep, elongated depression fronting a mountainous land area. (A geologic term which can include a submarine trench or trough.)

TRENCH.—A long and narrow submarine depression with relatively steep sides. (Converse of ridge.)

TROUGH.—A long and broad submarine depression with gently sloping sides. (Converse of swell.)

*c.* Deep-sea elevations:

PLATEAU.—An elevated feature having an extensive flat top, usually with rather steep side slopes.

RIDGE.—A long and narrow elevation with steeper sides than those of a swell. (Converse of trench.)

SEAMOUNT.—A submarine mountain rising more than 500 fathoms above the ocean floor. (See Knoll in **1682.**)

SWELL.—An extensive long and broad elevation which rises gently from the ocean bottom. (Converse of trough; supersedes former term *rise.*)

### *1682. Secondary Features*

*a.* Embayments (application of specific terms varies with locality):

BAY.—An extensive arm of the sea which is usually smaller than a gulf.

BIGHT.—A small open bay formed by an indentation in the coast; a minor feature which affords little protection for vessels.

COVE.—A small sheltered recess in a shore or coast, generally inside a larger embayment.

HARBOR.—A natural or artificially improved body of water providing protection for vessels, and generally anchorage and docking facilities.

INLET.—An arm of the sea, comparatively long with respect to its width and not restricted at its entrance, which may extend a considerable distance inland; or a relatively narrow passage connecting a virtually enclosed body of water with the sea.

*b.* Coastal features:

CAPE.—A relatively extensive land area jutting seaward from a continent or large island which prominently marks a change in or interrupts notably the coastal trend; a prominent feature.

COAST.—A zone of land of indefinite width bordering the sea; the littoral or coastal region.

HIGH-WATER LINE.—The line where the established plane of mean high water intersects the shore.

ISLAND.—A land area (smaller than a continent) extending above and completely surrounded by water at mean high water.

ISLET.—A very small and minor island.

LOW-WATER LINE.—The line where the established low-water datum intersects the shore. The plane of reference that constitutes the low-water datum differs in different regions.

POINT.—The extreme end of a cape, or the outer end of any land area protruding into the water; less prominent than a cape.

SHORE.—The narrow zone of land fronting any body of water.

SHORELINE.—The line of contact between the land and a body of water. (The line delineating the shoreline on Coast and Geodetic Survey nautical charts and surveys approximates the high-water line.)

*c.* Streams (application of specific terms varies with locality):

BAYOU.—A minor sluggish waterway or estuarial creek, generally tidal or characterized by a slow or imperceptible current, and with its course generally through lowlands or swamps, tributary to or connecting other streams or bodies of water. In the Gulf Coast region, Florida Peninsula, and lower Mississippi Valley, many specific meanings have been implied.

BROOK and RUN.—Minor streams always tributary to creeks and rivers.

CREEK.—A stream, less prominent than a river in any region, generally tributary to a river or another creek.

LAGOON.—A shallow body of water, as a pond or lake, which usually has a shallow restricted outlet to the sea.

RIVER.—A stream relatively prominent in any extensive region.

SLOUGH.—A minor muddy marshland or tidal waterway which usually connects other tidal areas.

*d.* Submarine depressions:

CALDRON.—A small deep of a general circular, elliptical, or oval shape.

CANYON.—A deep submarine depression of valley form with relatively steep side slopes.

SEAVALLEY.—A submarine depression of broad valley form without the steep side slopes which characterize a canyon.

VALLEY.—A prolongation of a land valley into or across the continental or insular shelf, which generally gives evidence of having been formed by stream erosion.

*e.* Submarine elevations:

BANK.—A non-coral or non-rocky area extending from the shore which may uncover and is a menace to surface navigation. (See Bank in **1681**.)

CREST.—The more or less narrow, irregular, longitudinal top of an elevated feature such as a ridge or seamount.

DOME.—A specific dome-shaped elevation with a characteristically rounded profile.

KNOLL.—A small submarine hill, or elevation, rising from the ocean floor, but which is smaller and less prominent than a seamount.

LEDGE.—A rocky formation continuous with and fringing the shore. The area that uncovers is usually represented on charts by symbols.

PINNACLE.—Any characteristic rocky column which is dangerous to surface navigation.

REEF.—Any coral elevation, or a detached rocky elevation that is dangerous to surface navigation and may uncover. A rocky reef is detached from shore but a coral reef may or may not extend from the shore. (See Bank in **1681**.)

SHOAL.—A detached non-coral or non-rocky area which is a menace to surface navigation and may shift in position or change in shape. (See Bank in **1681**. Reefs and shoals are

always menaces to surface navigation. Similar continental or insular shelf features of greater depth are usually termed banks.)

SPUR.—A prolongation of a land ridge onto or across the continental or insular shelf; or any minor submerged ridge; or a submerged ridge of lower elevation projecting or radiating from a larger and higher feature.

## 17. OPERATIONS BEYOND PROJECT LIMITS

Survey vessels when proceeding to or from their project areas should take every opportunity to verify the published charts and coast pilot information along their route, in ports at which they may call, and particularly in areas immediately adjacent to their project. Echo sounding has made it possible to obtain soundings along the route without material delay to the vessel.

### 171. Sounding en Route

Advantage should be taken of the transit of vessels to obtain information in blank or insufficiently sounded areas on the charts. It is frequently possible to make a slight deviation from the direct course between two places in order to pass over such areas. With echo sounding one line may be run across the area without delay in passage.

If the area is offshore and out of sight of land the voyage should be planned, if practicable, to arrive at the area shortly after sunrise so that an adequate astronomic fix may be obtained shortly before arrival.

Soundings obtained en route may be plotted on a copy of the largest-scale chart of the area, on which should also be shown the lines of position, if astronomic observations have been obtained. The chart should be forwarded to the Washington Office with a report discussing in full the circumstances and giving complete data regarding the control used.

### 172. Reported Shoals

Each survey vessel should investigate any reported shoals or dangers to navigation along a route, especially those marked *ED* (existence doubtful) or *PD* (position doubtful) on the charts. Circumstances will determine to what extent deviation from a prearranged route is justifiable in a given case. Such shoals or dangers as lie immediately adjacent to the project area should be thoroughly examined as opportunity affords. The project instructions will specify the type of examination to be made for those areas known to require special investigation.

There may be reported locally to the Chief of Party dangers to navigation consisting of rocks, reefs, shoals, or sunken wrecks either not charted or incorrectly charted and each of these should be investigated if the information is believed reliable enough to warrant it. Experience has shown that many such reports are untrustworthy either because they are based on discolored water or floating debris having been sighted or because the position reported is far from the true one. It is often very difficult to prove or disprove the existence of a reported danger, especially if it is out of sight of land. A preliminary investigation may only *tend* to prove or disprove its existence, requiring subsequent arrangements for a more thorough examination. In such cases the facts should be reported to the Washington Office by radio and instructions requested.

To make a thorough investigation to prove or disprove a reported danger out of sight of land, it is almost essential to use one or more survey buoys to ensure adequate coverage of the area (see **2535** and **2571**). Survey buoys can now be anchored

in depths greater than a thousand fathoms if the vessel is properly equipped (see **283**), but ordinarily they will not be needed unless depths considerably less than this are found during the preliminary investigation.

A complete and separate report of each investigation made shall be forwarded to the Washington Office at the earliest opportunity. The report should give the latitude and longitude of the least depth found and should include all of the sounding and control data, and a discussion of the methods of control used.

If a danger to navigation is discovered it must be reported immediately by radio (see **8522**).

### 173. Erroneous Soundings on the Chart

En route to and from the project area, or when navigating in the vicinity thereof, every opportunity should be utilized to verify the charted soundings, especially in areas in which the charted data are known to have been based on reconnaissance or inadequate surveys. Where an erroneous sounding is discovered, or where the general depths obtained differ materially from those charted, a full report of the facts shall be made to the Washington Office.

### 174. Aids to Navigation

Survey vessels should verify all aids to navigation along their routes or in the areas adjacent to their project, when practicable. The verification should consist of (*a*) a check of the charted position, (*b*) whether a lighted aid is burning, and (*c*) a comparison of the actual characteristics with those charted and listed in the Light List.

En route it will sometimes be practicable to verify only the lightships and offshore buoys, but in the immediate vicinity of the project area the positions of all aids to navigation, which have not been previously located by this Bureau, should be verified, if practicable.

When a lighted aid is found extinguished, immediate report should be made to the Commander of the nearest United States Coast Guard District. When a floating aid is discovered out of position, a report should be made both to the Coast Guard Commander and to the Washington Office. Where a fixed aid is found incorrectly charted either as to position or characteristics, a report should be made to the Washington Office, giving the correct position and the method by which it was determined. (See also **383** and **8531**.)

### 175. Coast Pilot Data

Advantage should be taken of all calls at ports and passages between ports to verify the information contained in the latest edition of the Coast Pilot for the area. If the information is correct but should be supplemented, the necessary data should be obtained (see **912** and **916**) and reported to the Washington Office at the earliest opportunity.

### 176. Field Examinations

When surveys of a minor nature are made outside of the project area, for which no specific instructions are written, they are considered *field examinations*. These are intended for revision only and are not registered in the archives as original survey sheets, but should be as adequately controlled as surveys called for by specific instructions. A field examination may consist of such items as (*a*) a resurvey by planetable of a point extended by accretion, (*b*) a planetable survey to locate a new pier or determine

the position of a new aid to navigation, (*c*) the determination of the least depth on a shoal of small area or the investigation of an area in which one has been reported.

The results may be transmitted to the Office on a section of a planimetric map, if there is one of the area, or on a section of the largest-scale chart of the area.

### *1761. Advance Information*

It is sometimes required that survey data in a small but important part of the project area be submitted to the Washington Office in advance of the completion of the entire survey. The required data may be traced on a piece of tracing paper containing meridians and parallels at the scale of the survey. These may be used for a preliminary correction of the chart but will be destroyed at a later date after the complete survey has been received and verified in the Washington Office.

# CHAPTER 2. CONTROL AND SIGNAL BUILDING

## 21. CONTROL

Control is the framework of a survey by which land and marine features are held in their true relationship to each other, and so determined by latitude and longitude that any area surveyed can be reproduced in its correct geographic position on any map or chart, regardless of scale or size.

At the start of any survey, available data of a higher order are the control for that survey. For example, first-order triangulation is control for second-order triangulation; second-order triangulation is control for third-order triangulation; and third-order triangulation is control for topographic, air photographic, and graphic control surveys. The control stations used in the hydrographic survey are ordinarily located as part of one of the last three surveys mentioned, but of course any or all of the control may be so used.

The control for a survey is a number of accurately located points marked on the earth's surface, strategically situated and spaced with respect to the survey. These points must be fixed geographically in order that they may be plotted on a projection or grid. The principal control points are most accurately determined by triangulation. There are areas, however, where triangulation is difficult and it is more practicable to locate control points by traverse; for example, along a stretch of sand beach, bordered by an adjacent precipitous mountain area.

Previously established control is a very important asset in a coastal survey. Sometimes a sufficient number of former stations will be recovered to control a revision survey and no new control will be necessary. Most surveys, however, require new triangulation of second- or third-order accuracy, supplemented by topographic and hydrographic stations.

If triangulation control does not exist, a base must be measured for length control and astronomic observations must be made to determine the latitude and longitude of a station and an azimuth. The astronomic observations should be made preferably at one of the base stations or at one of the stations of the base net.

Topographic control based on existing or new triangulation is necessary, of course, after the positions of the triangulation control stations are known and available.

### 211. Definitions of Control Terms

Control terms as they apply to hydrographic surveys are defined in order that their precise application may be more thoroughly understood and to prevent ambiguity in their use.

In general, the correct terminology is dependent on the method of location and type of instrumental equipment used, modified in certain cases by the accuracy attained and whether or not an adequate check on the location has been provided.

A triangulation station must be of third-order accuracy or higher, and any stations, located by geodetic methods, which do not comply with the requirements nor attain third-order accuracy, are classified as topographic stations. Among the latter are: (*a*) Intersection stations located by single triangles, one angle of which is con-

cluded; (*b*) intersection stations located by an insufficient number of directions to provide an adequate check of their positions; (*c*) stations located by theodolite by the three-point problem, without a check; (*d*) temporary stations, located by geodetic methods, but which are unmarked and nonrecoverable; and (*e*) stations located by any method or scheme, which depends in part on floating or movable stations. The last classification applies particularly to stations located by the ship- and buoy-intersection methods, described in **2282** and **2283**, or similar methods.

Distinction is made between *topographic* and *hydrographic* stations according to the methods of location.

### *2111. Stations and Signals*

A *station* is a definite point on the surface of the earth whose geographic position has been determined for control purposes.

The term *signal* denotes the object, existent or especially erected, which indicates the location of the station, and is used as a target toward which survey instruments may be pointed.

Stations may be marked points (permanent or temporary) or they may be conspicuous artificial or natural objects. If the latter, the station is the center of the object which is the signal.

### *2112. Triangulation Station*

A triangulation station is a recoverable point on the surface of the earth, whose geographic position has been determined by angular methods with geodetic instruments. It must be located with first-, second-, or third-order accuracy (see pp. 1 to 5, Special Publication No. 145).

A triangulation station is a selected point, which has been marked—lately always with a standard station mark --or it is a conspicuous natural or artificial object.

Descriptions are written of all triangulation stations.

### *2113. Traverse Station*

A traverse station differs from a triangulation station only in that its position is determined from another known point by linear measurements controlled in azimuth by angular measurements, instead of by angular methods solely.

### *2114. Topographic Station*

A topographic station is a definite point on the surface of the earth, whose geographic position has been determined by graphic methods, usually by planetable traverse or graphic triangulation.

Classed also as topographic stations are those points located by geodetic methods but with less than third-order accuracy, as mentioned in **211**.

Points located by the radial-line plot of an air photographic survey, specifically for use in a hydrographic survey, are also classed as topographic stations, as well as all stations that are symbolized by a red circle in accordance with **2393**.

A topographic station may be recoverable, if it is marked by a standard station mark or is a conspicuous natural or artificial object; or it may be temporary, usually for use in the subsequent hydrographic survey.

Descriptions are written of recoverable topographic stations.

### 2115. *Hydrographic Station*

A hydrographic station is one whose geographic position has been determined by methods ordinarily used only in hydrographic surveys and with an accuracy usually less than that of a topographic station.

The positions are generally determined by sextant observations—three-point fixes, intersection of cuts, or astronomic observations.

Also classed as hydrographic stations are those located by taut-wire traverse, log-distance runs, R.A.R. distances, and other less accurate methods.

Hydrographic stations are ordinarily not permanently marked; but if they are marked, a standard topographic station mark is used and a description is written (see **245**).

### 2116. *Hydrographic Signal*

A *hydrographic signal* is any signal used as a target in measuring sextant angles for the control of a hydrographic survey, irrespective of the method by which the station was located.

## 212. Frequency and Spacing of Control

The spacing of control depends on the nature and character of the coastline. The number and distribution of stations shall be such that all topographic and hydrographic features and soundings within the area of the survey can be located with sufficient accuracy for charting at the largest scale likely to be necessary.

Triangulation or traverse stations must be frequent enough along the coast to control the planetable or air photographic surveys. The required frequency depends on the scales of the surveys and the configuration of the coastal area, or the area covered by air photographs.

Bases must be measured at intervals along the arc or scheme of triangulation in order that the strength of the triangulation may be in accordance with the specifications for the class of triangulation being established, as specified in the requirements for horizontal control given in table 3 in **223**.

Where practicable, main-scheme (second-order) triangulation stations shall be spaced about 5 miles apart along the coast, with supplemental stations of third-order accuracy about 2 miles apart for topographic control (see **2231**).

In addition to the triangulation control, a considerable number of intermediate stations are necessary for hydrographic control. Experience is the best guide in the establishment of adequate control for this purpose. Stations should be located at prominent points and at the heads of small bights, and in general so spaced that strong fixes will be available throughout the area of the survey. But an excess of stations should be avoided, for it leads to confusion and increases the difficulty of identification when taking sextant angles.

For launch hydrography, stations spaced about 400 meters apart along the shore will usually suffice. Stations should be located well inshore from the beach, if practicable, so that strong sextant fixes may be obtained when the launch is near the shoreline.

For offshore visual ship hydrography, control stations may be several miles apart if structures are built over them, or if they consist of peaks, mountain tops, or prominent natural objects.

Hydrographic surveys of moderate depths, out of sight of land, are usually controlled by sextant fixes on buoys, spaced from 2½ to 5 miles apart, depending on the visibility, the scale of the survey, and the importance of the area being surveyed.

For offshore surveys controlled by R.A.R., the required spacing of the stations depends on (*a*) the size and scale of the survey, (*b*) the efficiency of reception of subaqueous sound, and (*c*) whether shore stations or sono-radio buoys are used. Sono-radio buoys are usually spaced 10 to 20 miles apart, while shore stations are spaced 15 to 30 miles.

### 213. Accuracy of Control

The accuracy of the control stations of a hydrographic survey depends almost directly on the method used in locating the control. The accuracy requirements for control located by triangulation or traverse are given in **223**, and the requirements for control located by planetable or air photographic surveys are given in **232**.

When nonstandard methods of locating control are used in places where standard methods are impracticable, they are expected to result in a lesser accuracy than the standard methods for which they are substituted, but special care taken in making the observations and special attention to details should in each case result in an accuracy no less than that of the next lower order of control.

Definite objects along the shore located by the topographer for the hydrographic party should be located with the accuracy required in **232**. A lesser accuracy may be tolerated in the positions of indefinite objects such as hills and mountain peaks, because they will be used by the hydrographer only when he is at a considerable distance from them.

Survey buoys, which are used for control beyond the range of shore stations, should be located by the most practicable and accurate method for which the vessel is equipped. Taut-wire sun-azimuth traverses are considered to give an accuracy of approximately 1 meter per mile.

Whether offshore hydrography is controlled by visual three-point fixes on shore stations, mountain peaks, or a system of survey buoys connected to shore control, the accuracy of location of any sounding is almost inversely proportional to its distance from the shore.

### 214. Recoverable Stations

Stations artificially marked by recognized surveying organizations and well-defined natural or artificial objects, whose geographic positions have been accurately determined by triangulation, traverse, topography, sextant angles, or other accurate means, and which have been described, are termed recoverable stations.

Control stations located approximately a century ago were marked by various means such as: redwood stakes on the West Coast; cypress poles, center marked by a copper tack, in marshy areas of the Southern States; earthenware crocks and flowerpots buried in the ground in the Middle Atlantic States; and buried bottles in arid areas. In rocky areas they were marked by chiseled crosses, plain drill holes, and drill holes into which molten lead was poured or brass bolts or plugs were set. Numerous ingenious types of marks were used which were considered the best practicable with the materials and equipment available. Many of these stations have been recovered in the past and some of them quite recently. When recovered now they are always re-marked according to present standard specifications (see **2261**).

As the value of more permanent marks became apparent, the trend changed toward marks of a more durable character. Metal marks began to be used in areas where there were no rocks. Among those used were cones, capped rods, and trough-shaped marks for sand beaches and similar areas. Since most of these marks were made of cast iron, it became obvious that, because of rust and corrosion, the problem of permanent marks

was far from solved. Cement was then used to cast concrete blocks and posts for survey marks, with crosses or bolts in the top defining the center. This type of mark solved the problem of corrosion, but only a very limited amount of lettering could be cut or molded into the top of the mark to provide future identification, and to inform the public of the purpose of the mark and the importance of not moving or destroying it.

Small metal disks were designed about the beginning of the twentieth century for use as station marks. These can be set in concrete blocks or cemented in drill holes in outcropping rock, boulders, etc. The legends on the marks have been changed from time to time. At present, the disks of the Coast and Geodetic Survey have identifying symbols denoting the type of station, and have legends giving the Bureau's name as the establishing agency, explaining how to obtain information relative to the stations and the penalty imposed by law for malicious destruction. The name of the station and year it was established are stamped in the space provided near the center of the disk. The standard disks of the Coast and Geodetic Survey are of cast bronze, 3⅝ inches in diameter, with a shank 2⅞ inches long split at the end for spreading to anchor it more securely when placed in a concrete block or drill hole. Other surveying organizations use similar metal disks of bronze, brass, or aluminum.

Many natural and artificial objects whose positions are determined require no marking to make them recoverable. Some of these, such as sharp mountain peaks, pinnacle rocks, and conspicuous boulders will very probably last for eternity. Others are lone trees, beacons, water tanks, smokestacks, church spires, radio towers, lighthouses, etc., and will last only a few generations or less. Isolated objects are especially prominent and easy to recover.

### *2141. Frequency of Recoverable Stations*

In changeable areas, where resurveys are expectable because of natural or artificial changes, recoverable stations shall be established at 1-mile intervals along the coast, conveniently located to serve as control for future topographic or hydrographic surveys.

In isolated areas, along difficult coastlines, and where natural or artificial changes are not expected, recoverable stations shall be established at not less than 2-mile intervals.

### *2142. Descriptions of Recoverable Stations*

All triangulation stations shall be described on Form 525, Description of Triangulation Station, in accordance with **227**. All recoverable topographic and hydrographic stations shall be described on Form 524, Description of Recoverable Hydrographic or Topographic Station, in accordance with **2351**. The detailed descriptions of well-defined natural or artificial objects may be brief but must be thorough and made with care, to avoid confusion or doubt about their recovery at some future date.

The descriptions of structures, such as lighthouses, flagpoles, and water tanks are particularly important. These are subject to removal and replacement in adjacent locations, where the new structure may be mistaken for the former one unless the circumstances are known. Errors may thus be introduced in the survey which may be difficult to detect and, when detected, the source of the error may be very difficult to determine. Descriptions of lighthouses shall include the dates of their establishment, their heights, and brief descriptions of their appearance. Descriptions of water tanks must be made with even more care, and must include the names of the companies or organizations owning them; their locations, with measured distances to adjacent

streets, roads, or other features; and their heights and structural appearances. A description such as "Water Tank, Port Angeles, Washington," is inadequate and not acceptable. Ten or twenty years later a new survey may be made in the vicinity and there may be two water tanks in the locality where only one was expected. There will be doubt as to which was the one located. Still worse is the possibility that there may be only one water tank in the town, as expected, but the described water tank has been torn down since the prior survey and a new one erected in an adjacent location. If this is not known and the water tank is used as a control station in a hydrographic survey, before its position is checked, serious errors may result.

All objects of a recoverable nature, particularly lighthouses, church spires, cupolas, towers, stacks, flagpoles, etc., whose positions are worth determining are considered to be of sufficient importance to require descriptions, especially if they serve as landmarks or will be of value as control stations for future hydrographic surveys. To obtain adequate data for a description, it is essential to visit the site of the object to be described. Likewise, when objects of this type, whose positions have been determined by prior surveys, are used for the control of revision or new surveys, each site should first be visited for positive identification, and to establish beyond doubt that it has not been moved in location since the date of the original description. The necessary information may sometimes be obtained by correspondence or by personal inquiries from reliable sources, but certain identification is assured only by an actual visit to the site.

Unmarked whitewashes, banners, clumps of bushes, and signals located for temporary use in hydrographic surveys are, of course, not recoverable stations and need not be described.

## 215. Control Station Names

For purposes of identification and convenient reference, names are assigned to the control stations used in a hydrographic survey. In the assignment and use of such names, the following general principles should be observed, irrespective of the type of station being considered (see **2151**):

(*a*) All references to a station shall be by the name assigned to it.

(*b*) The same name shall be retained for a station during its existence or as long as it is used.

(*c*) Different names shall never be assigned to the same station, even in different surveys.

(*d*) Descriptive, geographic, or personal names which contain a natural reference to the station are preferable to arbitrary ones (see **2151**). For example, where a station is on or near a named geographic feature, or is an artificial object such as a spire or tank.

(*e*) Recovered stations used in a survey shall always retainthe original names assigned to them, except in the case of triangulation stations with unnecessarily long names, when a short name may be substituted for hydrographic use. The new name may consist of syllables of the original name (e. g., NIKOL for NIKOLSKI, 1938). (See **2154** and **744**.)

(*f*) A duplication of names must be avoided in the same locality and especially within the limits of the same hydrographic sheet.

### *2151. Types of Station Names*

The length of an arbitrary name assigned to a control station shall reflect in a general way the relative importance of the station named. Certain definite advantages accrue from such a system of naming. To accomplish the purpose, names for the various types of control stations shall be selected in accordance with the following rules:

(1) Names of five or more letters—triangulation and traverse stations.

(2) Names of four letters—marked topographic stations; sono-radio buoys; R.A.R. shore

stations; and temporary topographic and hydrographic stations used in ship hydrography.

(3) NAMES OF THREE LETTERS—temporary topographic and hydrographic stations used in small-boat hydrography; and ordinary survey buoys.

Where the inshore hydrography precedes the ship hydrography, the requirements of rules (2) and (3) shall be complied with as far as practicable. The small-boat party shall anticipate, if possible, the stations likely to be used by the ship, and assign four-letter names to them.

### *2152. Selection of Station Names*

To avoid confusion in the records, names should be selected that can be spelled and pronounced in only one way. The use of combinations of letters that are pronounced the same as other more common words but are spelled differently, should be avoided. For example, TAK and TUN should not be used because they are pronounced the same as TACK and TON, respectively.

The hydrographer should keep current an alphabetical list of names as they are adopted for use on his sheet. All three-letter names must be selected from the list in table 42 in **965**. Copies of this list can be obtained from the Washington Office and can be used as a check list of assigned names. A study of this list will also be helpful in the correct selection of four- and five-letter combinations.

### *2153. Assignment of Names on the Hydrographic Sheet*

So far as practicable and insofar as it does not conflict with other provisions herein, the control stations on a hydrographic survey sheet shall be assigned names that proceed alphabetically along the shoreline from left to right as viewed by the hydrographer during his survey. The names shall be so selected that the one at the approximate midpoint of the survey begins with a middle letter of the alphabet.

Where ordinary survey buoys are used for control, the names shall be arranged alphabetically for each line of buoys to satisfy the above requirements as nearly as practicable.

Such an arrangement of names has many advantages, both during the survey operations and during any future use of the survey sheet where quick identification of a particular station is necessary.

This method of assigning names does not supersede the general principles of naming stations outlined in **215**(*c*), (*d*), and (*e*).

### *2154. List of Stations in Sounding Records*

An alphabetical list of the stations used on a hydrographic survey sheet, together with their origins, shall be prepared and pasted in volume 1 of the Sounding Records following the title page. The list should be in the following form:

*List of stations on H-6374*

| Name used in hydrographic survey | Origin of station |
|---|---|
| NIKOL | NIKOLSKI, 1938 |
| PAW | T-5869 |
| REV | H-6373 |
| TOM | Volume 1 |

When a triangulation or traverse station has been used, the complete name with the year of establishment is necessary. Topographic stations, and hydrographic stations originating with some other hydrographic sheet, shall be referenced by the sheet number (registry, if known, otherwise the field number). A hydrographic

station which originates with the instant hydrographic survey shall be referenced by "volume 1," which will contain an index of the cuts used to locate that station (see **819***d*).

### *2155. Assignment of New Station Names*

All marked control stations as well as triangulation stations that are natural objects or artificial structures, must be named at the time of their establishment or location. Other stations established for hydrographic control shall be named by the hydrographer, insofar as practicable.

### *2156. Names of New Triangulation Stations*

New and distinctive names shall be assigned to all new triangulation and traverse stations, except as provided in the fourth paragraph of this item. Where possible, names with individuality shall be selected. If practicable, a station shall be named after some natural geographic feature near which the station is located, such as a bay, river, mountain peak, or town; or it may be named after the owner of the property on which it is located. The use of the property owner's name gives him a personal interest in the station and may aid in the preservation of the station mark. It is essential that such names be spelled correctly and every effort must be made to this end. Once the name has been stamped on the disk and becomes a part of the records it cannot be changed.

Where arbitrary names are selected they shall follow the rule in **2151**(1.)

Long descriptive phrases applied as names to artificial landmarks, in an attempt to make the names serve as descriptions of stations, are particularly objectionable.

A station which replaces a lost station shall always be given the name of the original station followed by the numeral 2, 3, etc., depending on the sequence of establishment of the new station. Thus, if station NOLAN is lost and a new station is established nearby, the assigned name must, without exception, be NOLAN 2. If the latter is lost and a third station is established the name must be NOLAN 3. This practice shall also be followed when, for any reason, it becomes necessary to establish a new station within an easily taped distance of an existing station. Under no circumstances should such a new station be named NOLAN ECCENTRIC (see **2261**).

All triangulation and traverse station names shall be followed by the year of establishment.

### *2157. Names of Relocated Buoy and Hydrophone Stations*

A buoy station is the position of the anchor and therefore any station names assigned to buoys are the names of the anchor positions.

When for any reason a survey buoy is moved to a new anchor position and relocated, a new name shall be assigned to the new location. This applies to buoys and R.A.R. shore hydrophones that have dragged or have been picked up for servicing and relocated in a position slightly different from the original location.

If desired, the last three letters of a shore hydrophone name may be composed of the radio call letters of the shore station, prefixed by a single letter which shall be changed for each different location of the hydrophone.

### *2158. Names of Natural Objects or Structures*

Natural objects, whose locations have been determined for use in hydrographic surveys, shall be named according to **2151**, except where a geographic or a descriptive

name is more desirable (see **2156**). When the natural object is identified by a geographic name, it is almost invariably preferable to use the geographic name or a part of it for the station name. Similarly with structures, it is preferable to select a station name which will identify the structure by description or proper name.

### 216. Control Stations of Other Organizations

Whenever control stations established by other organizations are known to exist in an area to be surveyed, an effort shall be made to connect the new control to a sufficient number of the stations of the other organization so that the two surveys may be coordinated. These connections shall be made unless the progress of the party would be materially delayed thereby, or the cost of the project would be materially increased because of the necessity of building and establishing intermediate stations or extending the scheme any considerable distance in order to make the connections.

Such connections should be made by triangulation or traverse for geodetic coordination. If a geodetic connection is impracticable, a graphic connection should be made by topography. The use of marked stations of other organizations as a part of the control, instead of establishing new stations in the immediate vicinity, is authorized and encouraged, provided they are connected to the federal control network, that their locations are satisfactory for control purposes, and that the station marks are in good condition and conform to the usual standards as to method of establishment, size. strength, and durability. (See **224**.)

### 217. Datums

#### *2171. Geodetic Datums*

A geodetic datum consists of five quantities: the latitude and longitude of an initial point, the azimuth of a line from this point, and two constants necessary to define the terrestrial spheroid. It forms the basis for the computation of horizontal control surveys in which the curvature of the earth is considered.

The Coast and Geodetic Survey has used two principal spheroids of reference for its geodetic work. Bessel's spheroid of 1841 was used from 1844 to 1880 when it was replaced by Clarke's spheroid of 1866. Clarke's determination is considered the more precise, and later observations have shown that for this part of the globe it represents the true figure of the earth somewhat better than the spheroid of Bessel.

During the early years of the Bureau's operations many detached triangulation systems existed in the United States, each based on independent astronomic observations within its system. With the completion of the first transcontinental arc of triangulation in 1899, the various detached systems were connected and a coordinated system based on a single geodetic datum was established for the whole country.

Station MEADES RANCH in central Kansas was selected as the basis for this single geodetic datum because it was near the center of area of the United States and because it was common to two great arcs of triangulation extending across the country, one along the 39th parallel and the other along the 98th meridian.

The best theoretical position of this station on the adopted spheroid of reference was found to be so near the value obtained by continuous triangulation from the New England States that the latter was adopted to save the labor of a vast amount of recomputation. The adoption of this datum, therefore, did not change the geographic positions of the then completed triangulation in New England and along the Atlantic Coast to North Carolina, nor in the states of New York, Pennsylvania, New Jersey,

and Delaware. In 1901, the adopted datum was officially named the "United States standard datum," and in 1913, with its adoption by both the Dominion of Canada and the Republic of Mexico, its designation was changed to the "North American datum."

In 1927 a unified adjustment was begun of all the first-order triangulation in the country in order that certain unavoidable discrepancies that had accumulated in the various arcs of triangulation would be systematically distributed throughout the whole network. In this adjustment the latitude and longitude of station MEADES RANCH were held fixed, but a new value of the azimuth to station WALDO was adopted based on the various Laplace azimuths distributed through the network. To distinguish between values on the North American datum and values in the new adjustment, the term "North American datum of 1927" was adopted. The position of MEADES RANCH on this datum is:

| | | | |
|---|---|---|---|
| Latitude | 39° | 13′ | 26″. 686 |
| Longitude | 98 | 32 | 30. 506 |
| Azimuth to WALDO | 75 | 28 | 09. 64 |

Computed on Clarke's spheroid of 1866.

A station is said to be on the North American datum of 1927 when it is rigidly adjusted to the scheme of the readjusted triangulation.

All hydrographic surveys in waters bordering continental United States are now made on the North American datum of 1927. However, independent geodetic datums exist in the territories and insular possessions of the United States and the surveys therein are, with minor exceptions, based on the datums listed below:

| | |
|---|---|
| Hawaiian Islands | Old Hawaiian datum |
| Philippine Islands | Luzon datum |
| Puerto Rico and vicinity | Puerto Rico datum |
| Canal Zone | Panama—Colón datum |
| Alaska: | |
| Southeast Alaska | North American datum of 1927 |
| West of Glacier Bay to Mt. St. Elias | Southeast Alaska datum |
| The 141st meridian | Yukon datum |
| Cape St. Elias to Wide Bay on the Alaska Peninsula (including Kodiak I.) | Valdez datum |
| Latitude 57¼°, Alaska Peninsula to Atka I., Aleutian Islands | Unalaska datum |

And various independent astronomic datums.

To differentiate between an independent datum and the North American datum of 1927: An independent datum is established primarily for horizontal control over a limited area with reference to an assumed starting point, whose position on the spheroid of reference by latitude and longitude and whose azimuth to an adjacent station have been determined astronomically, but which has not been connected to the standard datum of the continental area.

The hydrographic surveys bordering those limited areas are naturally controlled by their respective datums. However, all independent datums on the North American Continent will probably be connected to the North American datum of 1927 at some future date, thereby making it possible to bring them into the general adjustment.

### *2172. Sounding Datums*

For use on the nautical charts of the tidal waters of the United States and its insular possessions and territories, planes of reference or sounding datums have been chosen in accordance with existing conditions. The sounding datum for depths is mean low water (MLW) for the Atlantic Ocean and Gulf of Mexico; and mean lower

low water (MLLW) for the Pacific Ocean, except in the vicinity of the Panama Canal Zone where it is mean low water springs (MLWS).

For further information on planes of reference, see **8224**.

### *2173. Vertical Datums*

The vertical datum for elevations, contours, and form lines for topographic surveys and nautical charts is mean high water (MHW) for the United States and its insular possessions and territories (see **2311**), except underlined elevations of inland mountain peaks on charts, which are referenced to mean sea level.

## 22. TRIANGULATION

Complete instructions and specifications for triangulation are contained in Special Publication No. 120, Manual of First-Order Triangulation, and Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse. Except as modified in the project instructions, these manuals shall be followed by hydrographic parties engaged in triangulation. Only the briefest discussion of the subject can be included in this Manual, which is only concerned with some special applications and methods of triangulation particularly adapted to hydrographic surveys.

A triangulation scheme is a continuous chain of connected triangles in figures of single triangles, quadrilaterals, and polygons, beginning with a line of known length and azimuth, the latitudes and longitudes of the end stations of which have been previously determined.

When the length of one line in a triangle and the interior angles are known, the other two lengths can be computed. Similarly, knowing the latitudes and longitudes of two stations, the azimuth between them, the lengths of the two lines to a third station, and the spherical angles in the triangle (from computation of triangles), the latitude and longitude of the third station and the azimuths of the other two lines can be computed.

### 221. General Statement

Triangulation is seldom an end in itself; its real value is more in its usefulness for other purposes than in its immediate objective, and this is particularly true of coastal triangulation, which serves as control for hydrographic and topographic surveys along the coast, and on the adjacent rivers and inside waters.

To be of most value, such triangulation stations must be established with this in mind and be placed where they will be as accessible and useful as possible for the control of the subsequent topographic and hydrographic surveys. Wherever practicable they should be placed on points, headlands, hillocks, and other places where they command strategic views of the shoreline in all directions. In some localities this is easily accomplished, especially where there is high land immediately inshore from the coast, and highways and navigable waterways paralleling the shore make transportation a simple matter. Elsewhere there may be unfavorable conditions along the coast, such as the swamps along the coastlines of Louisiana and South Carolina, the rugged coastlines of rocky islands, or the mountainous areas of Alaska.

Sextant locations should not be substituted for triangulation, except in an emergency. In general, important stations and landmarks such as lighthouses, tanks, and prominent buildings should be located by triangulation or traverse.

In planning the establishment or extension of a scheme of coastal triangulation, there are certain requirements, common to all projects, which may be enumerated as follows:

(*a*) Efficiency in reconnaissance. The scheme should be the strongest practicable under existing conditions.

(*b*) Economy in stations and signal building. The scheme should not contain more stations than needed to provide the required control. The stations should require a minimum of signal building.

(*c*) Permanence of stations.

(*d*) Accurate and systematic observing.

(*e*) Coordination of triangulation with other ship or shore party operations.

(*f*) Accessibility, not only for the observing party, but for the topographic party and those other organizations and individuals who, at some future time, may wish to make use of the stations and lines established.

(*g*) Provision for future lateral expansion of the scheme and for possible additional stations inside the figures themselves.

### *2211. Principal Scheme*

The principal scheme of triangulation shall be carefully planned. New triangulation, except in areas where a geodetic datum has not been established, must be started from a previously established line of first- or second-order triangulation. All necessary lines of the principal scheme must be observed, if practicable. Superfluous lines must not be observed, however, for not only is valuable observing time thus lost but the resulting triangles are useless and complicate the office adjustment.

In the principal scheme, an occasional unoccupied station may be tolerated, but should be avodied if practicable. Too many concluded angles in the principal scheme are objectionable.

The computation of triangles must be kept up with the observations in order to verify their accuracy by the length and side checks. The field computations through the determination of geographic positions, with accompanying list of geographic positions, should be forwarded to the Washington Office with the other records.

There is no restriction on the number of unoccupied stations and concluded triangles which may occur in the location of supplemental or third-order stations, provided the length and side checks are satisfactory.

### *2212. Spherical Excess*

Spherical excess is often a factor in the computation of triangles. The ratio of spherical excess to the area of a triangle is 1 second for 75 square statute miles. For preliminary use in closing triangles, the spherical excess can be computed from the graphically scaled lengths, in statute miles, of the base and altitude of a triangle by applying the formula:

$$\text{Spherical excess (in seconds)} = \frac{\text{base} \times \text{altitude}}{150}$$

For the computation of triangles, spherical excess is computed by logarithms and for second- and third-order triangulation need be carried only to tenths of seconds. (See specimen of computations, page 94, Special Publication No. 145.)

### *2213. Observing Weather*

Consistently good results can be obtained only by the use of the best grade of instruments in the best observing weather. It is wasted effort to attempt observa-

tions in storms, heavy rain, or strong winds, and survey parties should not be detailed ashore for triangulation observations in threatening or inclement weather. Poor runs, closures, and checks usually result from such observations, and it is quite probable that a station occupied under such conditions would have to be reoccupied. Accuracy is the first requisite of a traingulation survey and, as it is obtained, speed and progress naturally follow.

It should be realized, however, that the great accuracy of triangulation is required primarily to avoid accumulations of errors in the extension of the triangulation, and not to control the topographic and hydrographic surveys in a limited area. Where these await the advancement of the triangulation, no opportunity should be lost in expediting the observing. In such cases it may even be advisable for a time at least to take preliminary observations of a lower accuracy in order to provide control quickly.

In regions where good visibility is infrequent and its duration short and uncertain, owing to changeable conditions, low passing clouds, shifting fog patches, etc., economy in observing is obtained with the use of direction theodolites.

### *2214. Instruments*

Among the instruments used by the Coast and Geodetic Survey in establishing triangulation control for hydrographic surveys are the 9- and 6½-inch direction theodolites and the 7-inch repeating theodolites. The direction theodolites most frequently used were designed by D. L. Parkhurst, Chief of the Instrument Division of the Bureau, and are called Parkhurst theodolites. They are manufactured to order by reputable survey instrument companies. A manufactured tripod is not used with the 9-inch theodolite; the instrument is ordinarily used for observations from steel towers, but for observations from the ground it is mounted on a specially built wooden stand.

The distinctive features of this theodolite are its nonbinding centers, ball-bearing clamp rings, illumination through the central axis, electrically illuminated glass micrometer drums, discontinuous conical bearings for horizontal circle, and the use of nylon threads for the cross hairs of the telescope and for the micrometer wires. The 9-inch direction theodolties reading to single seconds on the horizontal circle are used principally for first-order observations when highly accurate results are required. The 6½-inch direction theodolites reading to 2 seconds on the horizontal circle are used principally for second-order triangulation and as much third-order work as practicable. Tripods constructed by the manufacturer are provided for the 6½-inch direction theodolite.

The repeating theodolites, reading to 10 seconds on the horizontal circle, are generally used for third-order triangulation when direction theodolites are not available or cannot be used because of the unstable condition of the ground or support of the instrument, or the limited space available for the observer, in which instances it is advantageous to be able to observe with a minimum of walking around the tripod.

### *2215. Instrument Stability*

Instability of the instrument is a frequent source of error in the observations, the importance of which is often not realized by an inexperienced observer. The clamps and foot screws of the instrument should be kept tight at all times. If a wooden stand 4 feet high is built to support the instrument, the observer should stand on foot boards supported by stakes driven in the ground well away from the legs of the stand. If an instrument tripod is used, it should be supported on 2- by 4- or 3- by 3-inch stakes

firmly driven into the ground. Where tundra or heavy moss is encountered, the roots should be cut around each tripod leg so the pressure from walking around or standing near the tripod legs will not disturb the azimuth of the instrument during observations.

The instrument and, if practicable, the stand or tripod, should always be shaded from strong sunlight.

### *2216. Sum Angles*

Sum angles must *not* be observed with a repeating theodolite. When additional lines must be observed from a station previously occupied, the new observations must include one and only one of the previously observed lines, except when check angles are observed to prove the recovery of old stations (see **225**).

For the observing program illustrated in *a* in figure 5, it is assumed that the observer at *A* observes the angles *DAE, EAF, FAB* and, being unable to see station *C*, closes the horizon by observing the angle *BAD*, as shown by solid lines and arrows. At a later date the observer returns to *A* when *C* is visible and correctly supplements his former observations by observing the angles *BAC* and *CAB* as shown in *b* in figure 5.

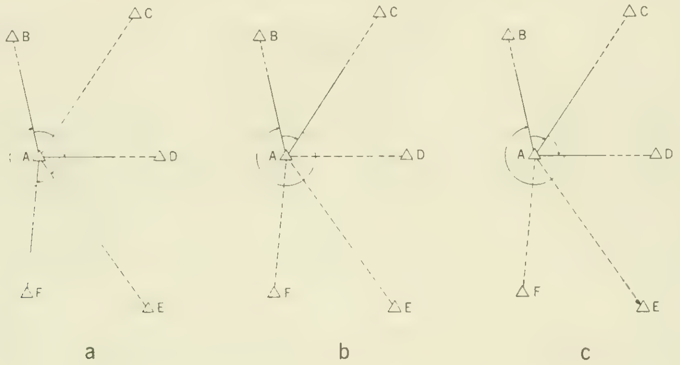


FIGURE 5.—Additional lines observed with repeating theodolite. (The correct procedure is illustrated in *a* and *b*; the incorrect in *a* and *c*.

The wrong method of observation is illustrated in *c* in figure 5. The angles *BAC, CAD*, and *DAB must not* be observed since they include two previously observed lines *AB* and *AD*. This results in a *sum* angle, since the sum of the angles *BAC* and *CAD* is equivalent to the previously measured angle *BAD* and will require a least square adjustment to distribute the difference in values properly. If the observations are made as stated in the previous paragraph, the angle *CAD* may be obtained by subtracting the angle *BAC* from the previously obtained value of the angle *BAD*.

When a direction theodolite is used in second- or third-order triangulation, the horizon is not to be closed by repointing on the initial. This results in a second value for the initial which must then be meaned with the first mean and is entirely unnecessary. Such observations are made only occasionally to test the plate for drag. (See figures 6 and 7 for methods of recording observations by direction and repeating theodolites.)

## 222. RECONNAISSANCE

The project instructions will specify the order and types of control to be established, the connections to existing stations, and the astronomic stations to be occupied or the bases to be measured. Special Publication No. 225, Manual of Reconnaissance for Triangulation, describes methods of ground reconnaissance for triangulation, computations for intervisibility of stations, strength of figures, etc.

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form 251a

Horizontal Directions

Station: GREEN 3 Observer: E.L.Atham Instrument: No. 312 Date: 10-30-40

| Position | Objects Observed | Time h. m. | Tel. D or R | Mic. | ° | ′ | Do not write in this margin / Do not write in this margin | Backw'd ″ | Forward ″ | Mean | Mean D and R | Direction ″ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MORSE 3 | 9 30 | D | A | 00 | 00 | | 23 | 24 | | | | CLEAR - COOL |
| | | AM | | B | | | | 27 | 29 | 258 | | | LIGHT NW BREEZE |
| | | | R | A | 180 | 00 | | 19 | 20 | | | | |
| | | | | B | | | | 18 | 20 | 192 | 22.5 | | |
| | NEW EDIZ HOOK L. H. | | D | A | 18 | 32 | | 30 | 30 | | | | |
| | | | | B | | | | 35 | 37 | 330 | | | |
| | | | R | A | 198 | 32 | | 25 | 26 | | | | |
| | | | | B | | | | 28 | 29 | 270 | 300 | 07.5 | 18° 32′ 07″.5 |
| | RACE ROCKS L. H. | | D | A | 51 | 33 | | 09 | 11 | | | | |
| | | | | B | | | | 15 | 16 | 12.8 | | | |
| | | | R | A | 231 | 33 | | 05 | 07 | | | | |
| | | | | B | | | | 55 | 57 | 01.0 | 06.9 | 44.4 | 51° 33′ 44″.4 |
| | BLUFF 3 | | D | A | 163 | 07 | | 15 | 17 | | | | |
| | | | | B | | | | 08 | 09 | 12.2 | | | |
| | | | R | A | 343 | 07 | | 00 | 02 | | | | |
| | | | | B | | | | 03 | 03 | 02.0 | 07.1 | 44.6 | 163° 07′ 44″.6 |
| | M^c DON | | D | A | 178 | 24 | | 35 | 36 | | | | |
| | | | | B | | | | 23 | 25 | 29.8 | | | |
| | | | R | A | 358 | 24 | | 20 | 21 | | | | |
| | | | | B | | | | 22 | 23 | 21.5 | 25.6 | 03.1 | 178° 24′ 03″.1 |
| | | | | | | | | | | | | | R. H. T. |

FIGURE 6.—Record of horizontal angles (direction theodolite).

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form 250

HORIZONTAL ANGLES

STATION: BETHEL STATE: ALA. ~~ISLAND OR~~ COUNTY: BALDWIN DATE: 5/15/35

OBSERVER: H. C. Ole INSTRUMENT: BERGER #179

| Objects Observed | Time h. m | Tel. D or R | Rep's | Angle ° ′ | Do not write in this margin / Do not write in this margin | A ″ | B ″ | Mean of Verniers | Angle Mean D and R ° ′ ″ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| WALTER - MIRTH | 1 30 | D | 0 | 00-00 | | 00 | 20 | 10 | | CLEAR - CALM |
| | P.M. | | 1 | 52-30 | | 40 | – | | | |
| | | | 3 | 157-31 | | 10 | – | | | |
| | | D | 6 | 315-02 | | 00 | 20 | 10 | 52-30-20.0 | |
| | | R | 6 | 00-00 | | 10 | 20 | 15 | 19.2 | 19.6 + 0.6 = 20.2 |
| MIRTH — ELLIS | | R | 0 | 00-00 | | 10 | 20 | 15 | | |
| | | | 1 | 45-49 | | 40 | – | | | |
| | | | 3 | 137-28 | | 30 | – | | | |
| | | R | 6 | 274-56 | | 40 | 30 | 35 | 45-49-23.3 | |
| | | D | 6 | 359-59 | | 50 | 50 | 50 | 27.5 | 25.4 + 0.6 = 26.0 |
| ELLIS — LYONS | | D | 0 | 00-00 | | 50 | 50 | 50 | | |
| | | | 1 | 57-17 | | 20 | – | | | |
| | | | 3 | 171-52 | | 20 | – | | | |
| | | D | 6 | 343-44 | | 50 | 50 | 50 | 57-17-30.0 | |
| | | R | 6 | 359-59 | | 20 | 20 | 20 | 35.0 | 32.5 + 0.6 = 33.1 |
| LYONS - WALTER | | R | 0 | 359-59 | | 20 | 20 | 20 | | |
| | | | 1 | 204-22 | | 00 | – | | | |
| | | | 3 | 253-07 | | 30 | – | | | |
| | | R | 6 | 146-15 | | 20 | 10 | 15 | 204-22-39.2 | |
| | | D | 6 | 359-59 | | 10 | 10 | 10 | 40.8 | 40.0 + 0.7 = 40. 7 |
| | | | | | | | | | 359-59 | 57.5 + 2.5 M.H.R. |

FIGURE 7.—Record of horizontal angles (repeating theodolite).

### *2221. Use of Air Photographs in Reconnaissance*

Reconnaissance for the selection of sites for control stations may be greatly facilitated by the use of suitable air photographs. Unless the air photographs are of the nine-lens type on a scale of 1:20,000 or smaller, or a carefully made mosaic is available, it will be advisable to make a preliminary compilation of the photographs and reduce the compilation to a small enough scale so that the control scheme may be plotted on a single sheet.

Generally a simple inspection of this plot, supplemented by examination of the photographs under a stereoscope, will be sufficient to select the sites for the triangulation stations along the shore. If the adjoining terrain has much relief or obviously advantageous means of access, it may also be practicable to select the sites for most of the inshore stations by simple inspection.

Approximate heights of tentative station sites may be determined from the photographs if a point of known elevation and the proposed station sites appear in the zone of overlap of two of the photographs. Heights may be *bridged* from one overlap to another, but large errors are likely to accumulate from the use of instruments and methods ordinarily available to the hydrographer in the field. Generally this will be unnecessary, since most of the air photographs taken in connection with hydrographic surveys will show portions of the coastline, thus affording ready reference to sea level.

To determine an approximate difference in elevation, the two overlapping photographs should be oriented very carefully under a stereoscope. Then the distance between the two photographic images of the point of known elevation and the distance between the two photographic images of the point whose elevation is desired should be measured to the nearest tenth of a millimeter. The difference between these two distances is called the difference in stereoscopic parallax $dp$. The distance between the centers of the two photographs on the preliminary plot, or base $B$, should also be scaled in meters. The symbol used for the known elevation is $h$. The altitude of the airplane $H$ is obtained from the ratio—focal length of camera $f$ divided by scale of plot $S$. The focal length of the camera and scale of the preliminary plot will be furnished with the photographs and other advance data. Thus for the nine-lens camera and a 1:20,000 scale plot:

$$H=\frac{209.75 \text{ mm } (f)}{1/20{,}000 \quad (S)}=4{,}185 \text{ meters}$$

The difference in elevation $dh$ is given by the equation:

$$dh=\frac{dp \text{ (in mm)} \times (H-h)^2 \text{ (in meters)}}{f \text{ (in mm)} \times B \text{ (in meters)}}$$

Thus for $dp$ equal to 2.0 mm, $H$ equal to 4,185 meters, reference point at sea level, $B$ equal to 2,000 meters, and $f$ equal to 209.75 mm:

$$dh \text{ (meters)}=\frac{2.0\times(4{,}185-0)^2}{209.75\times 2{,}000}=83.5 \text{ meters}$$

If straight lines are drawn, preferably with white ink, between possible sites for triangulation stations on each photograph, the lines will fuse to form lines in space when the photographs are viewed under the stereoscope. It will then be immediately apparent whether the lines are clear, blocked, or grazing. Reconnaissance on the ground may then be reduced to visiting the sites from which the doubtful lines radiate.

Study of the photographs under the stereoscope will also furnish valuable information relative to the types of signals needed, the best landing places, and routes to the stations.

## 223. REQUIREMENTS

In table 3 are given the requirements for triangulation and traverse control, which shall be strictly complied with, except as amended by the project instructions.

TABLE 3.—*Requirements for triangulation and traverse*

TRIANGULATION

| | First order | Second order | Third order |
|---|---|---|---|
| Strength of figures: | | | |
| Desirable limit, $\Sigma R_1$ between bases | 80 | 100 | 125. |
| Maximum limit, $\Sigma R_1$ between bases | 110 | 130 | 175. |
| Desirable limit, $R_1$, single figure | 15 | 25 | 25. |
| Maximum limit, $R_1$, single figure | 25 | 40 | 50. |
| Discrepancy between computed length and measured length of base or adjusted length of check line, not to exceed | 1 in 25,000 | 1 in 10,000 | 1 in 5,000. |
| Triangle closure: | | | |
| Average, not to exceed | 1 sec | 3 sec | 5 sec. |
| Maximum, not to exceed | 3 sec | 5 sec | 10 sec. |
| Usual number of observations: | | | |
| Positions with 1-second direction theodolite | 16 | 8* | 4. |
| Positions with 2-second direction theodolite | 24 | 12 | 4. |
| Sets with 10-second repeating theodolite | 5 to 6 | 2 to 3 | 1 to 2. |
| Rejection limits: | | | |
| Direction theodolite, 9- or 6½-inch | 4 sec | 5 sec | 5 sec. |
| Horizon closure: | | | |
| With 10-second repeating theodolite | | 1 sec. per angle | 1½ sec. per angle. |
| Base measurement: | | | |
| Actual error of base not to exceed | 1 in 300,000 | 1 in 150,000 | 1 in 75,000. |
| Probable error of base not to exceed | 1 in 1,000,000 | 1 in 500,000 | 1 in 250,000. |
| Discrepancy between 2 measures of a section, not to exceed | 10 mm $\sqrt{k}$ | 20 mm $\sqrt{k}$ | 25 mm $\sqrt{k}$. |
| Astronomic azimuth, probable error of result | 0.3 sec [1] | 0.3 sec [1] | |

TRAVERSE

| | First order | Second order | Third order |
|---|---|---|---|
| Closing error in position, not to exceed | 1 in 25,000 | 1 in 10,000 | 1 in 5,000. |
| Probable error of main scheme angles | 1.5 sec | 3.0 sec | 6.0 sec. |
| Number of stations between astronomic azimuths | 10 to 15 | 15 to 25 | 20 to 35. |
| Astronomic azimuth, discrepancy per main-angle station, not to exceed | 1.0 sec | 2.0 sec | 5.0 sec. |
| Astronomic azimuth, probable error of result | 0.5 sec | 2.0 sec | 5.0 sec. |

CIRCLE SETTINGS

*Initial settings for 10-second repeating theodolite*

| Position No. | 1 set | 2 sets | 3 sets |
|---|---|---|---|
| | ° ′ | ° ′ | ° ′ |
| 1 | 0 00 | 0 00 | 0 00 |
| 2 | | 90 05 | 60 02 |
| 3 | | | 120 04 |

*Initial settings for 2-micrometer theodolite*

Two Positions of Circle

| Position No. | 1 division of circle=4 minutes | 1 division of circle=5 minutes | 1 division of circle=10 minutes |
|---|---|---|---|
| | ° ′ ″ | ° ′ ″ | ° ′ ″ |
| 1 | 0 01 00 | 0 01 00 | 0 02 30 |
| 2 | 90 03 00 | 90 03 40 | 90 07 30 |

Four Positions of Circle

| Position No. | 1 division of circle=4 minutes | 1 division of circle=5 minutes | 1 division of circle=10 minutes |
|---|---|---|---|
| | ° ′ ″ | ° ′ ″ | ° ′ ″ |
| 1 | 0 00 30 | 0 00 40 | 0 01 20 |
| 2 | 45 01 30 | 45 01 50 | 45 03 50 |
| 3 | 90 02 30 | 90 03 10 | 90 06 20 |
| 4 | 135 03 30 | 135 04 20 | 135 08 50 |

Six Positions of Circle

| Position No. | 1 division of circle=4 minutes | 1 division of circle=5 minutes | 1 division of circle=10 minutes |
|---|---|---|---|
| 1 | 0 00 40 | 0 00 50 | 0 01 40 |
| 2 | 30 02 00 | 30 02 30 | 30 05 00 |
| 3 | 60 03 20 | 60 04 10 | 60 08 20 |
| 4 | 90 00 40 | 90 00 50 | 90 01 [illegible]0 |
| 5 | 120 02 00 | 120 02 30 | 120 05 00 |
| 6 | 150 03 20 | 150 04 10 | 150 08 20 |

Eight Positions of Circle

| Position No. | 1 division of circle=4 minutes | 1 division of circle=5 minutes | 1 division of circle=10 minutes |
|---|---|---|---|
| 1 | 0 00 30 | 0 00 40 | 0 01 20 |
| 2 | 22 0[illegible] 30 | 22 01 50 | 22 03 50 |
| 3 | 45 02 30 | 45 03 10 | 45 06 20 |
| 4 | 67 03 30 | 67 04 20 | 67 08 50 |
| 5 | 90 00 30 | 90 00 40 | 90 01 20 |
| 6 | 112 01 30 | 112 01 50 | 112 03 50 |
| 7 | 135 02 30 | 135 03 10 | 135 06 20 |
| 8 | 157 03 30 | 157 04 20 | 157 08 50 |

*Although only 8 positions are here specified, the practice of the Coast and Geodetic Survey is to use 16 positions. Very little additional time is required. The average triangle closure is decreased in this way from 3 seconds to about 1½ seconds.

[1] This is the requirement for a Laplace azimuth. In the recent practice of the Coast and Geodetic Survey the only azimuths observed are Laplace azimuths.

### *2231. Frequency of Triangulation Stations*

The frequency of second-order triangulation stations needed for the control of third-order triangulation and other control surveys of a lower accuracy cannot be governed by any fixed rule. Visibility, the character of the coastal area, and the practicable distance inshore from the coast at which the inshore side of the scheme can be established to give strong figures, are the main controlling factors. However, a scheme consisting of stations established so that the lengths of the side lines average about 5 or 6 miles will usually suffice.

For the control of planetable topography, second- or third-order triangulation stations shall be established along the coastline at intervals not to exceed 2 miles, except in areas of extremely unfavorable terrain where this would be exceedingly difficult and costly. In such cases the spacing may be increased, but shall never exceed 5 miles.

The control required for air photographic surveys will vary with the type of camera used, the scale of the photography, and the character of the terrain.

To control surveys made from air photographs taken with the nine-lens camera, recoverable triangulation stations shall be spaced as follows:

(*a*) For coastal surveys of comparatively flat areas at a scale of 1:10,000, stations shall be spaced not more than 4 miles apart along the shore, supplemented by inshore stations spaced not more than 6 miles apart.

(*b*) At intervals of about 8 miles an additional station, or stations, shall be established so as to furnish at least three stations within an area about 4 miles in diameter in order that each fifth photograph in the line of flight may be fixed by at least three control points within its limits.

(*c*) Approximately two-thirds as many stations must be established along the inland portion of the photographic strip as are provided along the shore.

(*d*) In harbors and in areas of special importance, at least 50 percent more control shall be provided than is required elsewhere.

(*e*) For a photographic survey on a scale of 1: 20,000, the spacing may be increased to approximately twice that which is required for a 1:10,000 scale.

Where the triangulation scheme spans a waterway with one side of the scheme on each shore, the same general spacing of stations, as outlined in (*a*), (*b*), and (*c*), is required, with additional or supplemental stations provided at intervals of 6 to 8 miles along the inland edge of the photographs for a survey on a scale of 1:10,000. The supplemental stations may be intersection or three-point fix stations.

The nine-lens photographs are 35.4 by 35.4 inches in size, and if the approximate centerline of a flight is known, the limits of the area photographed can be determined on a map or projection of suitable scale. Having determined these limits, the triangulation stations can be more effectively located to control the photographs. The spacing between centers of successive photographs along the line of flight will be 7, 12, or 14 inches, depending on the ruggedness of the terrain. The spacing between parallel flight lines will be 12 or 14 inches. If there are two or more parallel flights, the fixed photographs required in (*b*) should preferably be staggered along adjacent flights.

That an area is to be photographed for mapping does not exempt the observer of a triangulation unit from obtaining the usual cuts to conspicuous natural and artificial objects. These interesection stations will serve as valuable checks to the photographic plot and may considerably expedite the office compilations. In areas where accurately contoured topographic maps are not available, vertical angles should be measured to determine the elevations of the principal scheme and intersection stations, whenever this is feasible without materially delaying the progress of the triangulation party

## 224. Connection With Triangulation of Other Organizations

Independent schemes of triangulation, which have been established in the project area by other organizations, shall be connected to the triangulation of this Bureau by strong figures in such a way that their positions may be computed and adjusted on the North American datum of 1927, provided this is feasible. This provides additional control for the contemporary surveys and for any future surveys in this particular area by any agency. Such connections are especially desirable to the control stations of the United States Corps of Engineers, which are located in harbors and along inland navigable waterways, and the positions of their stations are valuable to the Bureau both for the control of surveys and for cartographic purposes.

Where a connection is to be made to triangulation of other agencies, a line connection is preferable to a point connection, because a comparison of the length and azimuth will give valuable data to be used in adjusting the scheme (see last paragraph on page 15, Special Publication No. 120, Manual of First-Order Triangulation). If neither method is feasible, a connection by topographic methods should be made (see **236**).

Representatives of other survey agencies should be contacted personally or by correspondence to ascertain what control exists within the project area, and to obtain positions and descriptions of stations and copies of the schemes. The latter will show the disposition of the stations and the area covered by the survey. To tie in the scheme properly, a connection should be made at three places strategically selected so that an adjustment of the triangulation of the other agency can be made to fit the triangulation of this Bureau.

If practicable, the positions of stations established by other organizations should be determined in lieu of establishing new stations nearby, provided the station marks are in good condition and the station sites are in suitable locations. In such instances, two standard Coast and Geodetic Survey reference marks shall be established at each station. The disks shall be stamped with the name given to the station by the establishing organization, followed by the initials of that agency and the year the reference marks are set, and numbered 1 and 2, provided no other Coast and Geodetic Survey reference marks have been previously established at the station.

Under no circumstances shall survey station marks of other organizations be altered or amended by stamping. Neither shall they be moved, replaced, or reset unless the project instructions so specify. However, they should be reinforced with concrete or by other methods that will tend to prolong their existence, especially if the mark is a little loose or in danger of being dislodged from its original position. Special precautions must be taken not to disturb or move the station mark in any way.

## 225. Recovery of Stations

Where new triangulation is connected to previously established triangulation, it is necessary to verify the identification and recovery of the old stations, and to check distances and directions to reference marks to ensure that the station marks have not been moved. The two stations at the ends of the old line must be occupied and observations made to a third station of the original scheme. If the measured angles check the original observations, the recovery of the old stations is assured.

To assist in keeping current the records of descriptions of triangulation stations, as well as to provide control for hydrographic surveys, the sites of all previously established control stations within the area of the survey should be visited, if practicable, and a thorough search made for each station and its reference marks. A report shall

be made of this search (see **2272**), but no station shall be reported "lost" unless an exhaustive search, or a change in the locality, establishes this fact beyond reasonable doubt. If such a search is impracticable, a statement relative to the extent of the examination shall be furnished so that all available information as to the status of the station may be properly noted in the office records.

Ephemeral objects such as flagstaffs, beacons, and signal towers, whose positions have been previously determined, shall not be used for control until they have been positively identified or their original positions have been verified (see **214**).

### 226. Station Marks

Each new station which is to be located by triangulation shall be marked with a standard bronze station-mark disk and at least two standard reference-mark disks of similar material, except well-defined natural or artificial objects located by intersection and substantially constructed objects, such as lighthouses and water tanks, where disks are unnecessary or marking impracticable.

When feasible, subsurface marks shall be established at all principal scheme second-order stations where there is any probability that the station mark may be disturbed. The subsurface mark shall be set in accordance with paragraph *c*, page 39, Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse. The disk in the subsurface mark shall be stamped identically with that of the surface mark. Subsurface marks are generally not required at third-order stations.

Azimuth marks shall not be established at second- or third-order triangulation stations unless the project instructions so specify. Because of the close spacing of stations, an adjacent station or some natural or artificial object will usually be visible and suffice for an azimuth mark.

Infrequently, marks are set for the location of a station but, before its position has been determined, the station is abandoned because the site is unsatisfactory due to obstructed lines or other causes. In such cases, the marks must be removed and the station destroyed.

In selecting a site for a station, it is always important to consider both the present and future use of the station. It is essential to have a location where the control station is the most effective for immediate use. For the control of subsequent surveys it is important to have a location and type of station mark that will remain intact and undisturbed for generations.

Triangulation stations shall be marked as permanently as possible, because, at a cost of several hundred dollars per station, it is poor economy to establish a station in a hasty haphazard manner so that it may soon be lost, when a little more effort and care would have resulted in a more permanent station. Each disk should be secured effectively in rock or concrete, to resist removal, change of elevation, or rotation. All lettering shall be stamped on the disk before it is set in concrete to avoid the possibility of breaking the inital set, thus loosening the disk. Where stations are established in locations frequented by the general public, they should be located where they will be most protected from acts of vandalism. Where they are established along the shore, they should be located, if practicable, where they will be immune from destruction by normal beach or riverbank erosion. Experience has proved that small terra-cotta tile, filled with concrete into which a standard disk is set, is a poor material for marking a station. The tile is easily broken, the core of concrete soon crumbles, and the station is lost. Further specifications and particulars for marking triangulation stations may

be found in pages 38 to 41, Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse.

### *2261. Resetting Station Marks*

Whether an old station is to be re-marked or not, often depends on the judgment of the person recovering the station. Under the following conditions, however, a station should always be re-marked:

(*a*) The old station is marked by a chiseled cross, a drill hole in rock, or some other method not using a standard bronze disk. In such instances the station should be re-marked by a standard disk, if this is practicable, so that the station will be better perpetuated and more easily identified and recovered.

(*b*) The disk in the recovered station mark is loose, the concrete block is cracked or is in poor condition.

(*c*) The station mark is destroyed but the subsurface mark is recovered without a question of doubt.

(*d*) The station mark is destroyed but two or more reference marks are recovered. A new station-mark disk can be established in the geographic position of the original station if:

(1) Two reference marks are recovered and sufficient evidence of the original station mark is found to assure the re-marking of the station without a doubt by the intersection of distance arcs swung from the reference marks, using the horizontal distances given in the description of station.

(2) Three reference marks are recovered and the three distance arcs intersect at a point, using the horizontal distances given in the description of station.

If the station mark is missing but the requirements in (*c*) or (*d*) are not met, and a station is needed in this locality, a new monument should be set and given the same name as the original station with the number 2 added as a suffix. (See paragraph 4 of **2156**.) This station must then be located by triangulation or traverse from adjacent stations. If the station mark is missing but none of the requirements in (*c*) or (*d*) is met and the station *is not* needed in this locality, then the marks should be left as found. (See **2272** relative to recovery reports.)

To ensure that the station is re-marked precisely in the original geographic position, construct a bench about 1 foot high over the station. The bench is constructed from a piece of 1- by 4-inch soft lumber supported by 2- by 4-inch stakes driven in the ground far enough away from the station so as not to be disturbed by the removal or resetting of the station mark. One end of the bench is nailed to the top of a stake by a single nail and the other end is swung into position on the other stake so that an edge of the bench is directly over the center of the old station-mark disk. In this position the free end is lightly nailed to its corresponding stake so that the nail penetrates the stake not more than one-fourth inch. With a plumb bob suspended directly over the station mark and the string running over the edge of the bench and across the top, the position of the string is marked by a small notch cut in the edge of the bench. The lightly nailed end of the bench is then pried off its stake, swung around out of the way and temporarily supported. The old mark is then removed, reinforced and reset, or replaced by a new mark and the disk set in the exact location of the original position by swinging the bench back into position, fitting the nail into its former impression and plumbing down from the notch in the edge of the bench. See illustration on page 5, Serial 632, The Preservation of Triangulation Station Marks.

The stamping of station and reference marks at control stations of other organizations is discussed in **224**.

### *2262. Relocating Station Marks*

When instructions are issued to a party to preserve, or move and relocate, a station endangered by a new highway, or other construction, one of the following methods shall be used:

(*a*) If the original horizontal position can be retained, but at a different elevation, and the bench method described in **2261** is impracticable, set two stakes preferably less than 30 meters and never

more than 100 meters from the station, so that lines from them to the station will intersect approximately at right angles. The stakes must be located where they will not be disturbed by the local construction, and spaced apart from each other and the station so that the focus of the instrument will not have to be changed during the measurements of the angles. This is important, for any change in focus when pointing from one station to another will likely affect the accuracy of the observations. Drive a projecting nail vertically in the top of each stake. With a theodolite centered over each nail and the station in succession, measure all three angles of the triangle formed by the two stakes and the station. Three positions with a 6½-inch direction theodolite or one set of 3D and 3R with a 10-second repeating theodolite closing the horizon, will be sufficient. Measure accurately the horizontal distance between all three points in the triangle.

After the construction has been completed, the station is re-marked by setting up again at each stake, preferably using two instruments simultaneously, sighting on the nail in the other stake and turning off the angle previously determined. At the intersection of the two lines of sight, mark a temporary point at any desired elevation. Check this location by measuring the angle at each stake with the same accuracy as before. If they are in agreement with the angles measured before construction, the station will be in its exact original geographic position when replaced. If one or more of the angles do not agree move the temporary mark slightly and repeat the measurements until an agreement is reached. Before measuring the angles, the horizontal distances previously measured should be checked. If more precise measurements are desired and if azimuth control is available, the geographic position of the replaced station can be computed and compared with the original geographic position.

(*b*) If the station has to be moved horizontally, establish a new mark or move the old one to a new position. The new location shall be determined by azimuth and distance measurements from the old station with at least third-order accuracy. The azimuth should be measured with three positions with a 6½-inch direction theodolite or one set of 6D and 6R with a 10-second repeating theodolite, and the horizontal distance taped twice (forward and backward), checking with an accuracy of at least one part in 5,000. Before or after the taping, the tape shall be compared with one which has been standardized. In determining the azimuth, another triangulation station should be used as the initial. Should an azimuth mark be available, it can be used in lieu of another station. If neither is available, use a natural or artificial object whose azimuth from the original station has been determined or can be computed. Should this be lacking use a reference mark. When moving a station mark, it is essential to hold the original position by a bench or other means, until the azimuth observations and distance measurements have been made to determine the position of the new station.

After the station mark has been established in the new position, occupy it to measure a direction to the azimuth mark, if there is one. Another triangulation station should be used as an initial, or the old station may be used if it is not too near.

### *2263. Rules and Examples*

All triangulation stations shall be marked or re-marked, and the disks stamped, in accordance with the following rules:

(*a*) Each newly established triangulation station shall be marked with a standard station-mark disk which shall be stamped with the name of the station and the year of establishment.

(*b*) Each reference-mark disk shall be stamped with the name of the station, the number of the reference mark, and the year.

(*c*) Each recovered station which is re-marked shall be stamped with the original name of the station, the original date of establishment, and the year in which it is re-marked.

(*d*) Additional reference marks may be established when a station is recovered and reoccupied. The name and date, or dates, on the reference-mark disks shall be the same as those on the station-mark disk at the time the reference mark is established.

(*e*) Do not renew an old reference mark. If it is in poor condition, either reinforce it or destroy it and set a new reference mark which will be numbered with the next consecutive unused number, regardless of the existence or absence of any of the reference marks established previously.

(*f*) The abbreviation "Ecc." (for eccentric) should never be stamped on a disk. Its use in the records should be solely to indicate that the observations made at that point must be reduced to the center station to close the triangles before being used in the subsequent computations.

(*g*) All stamping on disks for new station and reference marks shall be done with $\frac{3}{16}$-inch dies.

The following examples relative to stamping triangulation-station and reference-mark disks shall be strictly followed:

*CASE I*.—A new station is established. In the center of the station-mark disk is a small triangle. The year of establishment is stamped under one side and the name above the opposite apex of the triangle.

Two reference marks shall be established and the disks shall be stamped with the station name, number, and year. The reference marks shall be numbered consecutively in a clockwise direction from true north. They must be set so that the arrows on the disks point toward the station mark.

Special disks, used for azimuth marks only, can be obtained from the Washington Office by requisition. These azimuth disks shall be stamped with the name of the station and the year of establishment.

*Example*.—Station EAGLE is established in 1940. The disks shall be stamped as follows:

Station mark: EAGLE, 1940
Reference marks: EAGLE No. 1 (or 2), 1940
Azimuth mark: EAGLE, 1940

*CASE II*.—The station mark, reference mark, or azimuth mark is reinforced but not re-marked or otherwise disturbed in any way. If any or all of the above marks are reinforced only, the original stamping on the disks shall be retained without change, alteration, or addition.

*CASE III*.—The station is re-marked in the precise original location, and a new reference mark is established. The original name and date of the station shall be retained and, in addition, the year the station is re-marked shall be stamped under the date of original establishment. In re-marking the station, a new station-mark disk shall be set if none was used formerly, or if the original disk cannot be re-used.

If the two original reference marks are in good condition and in no danger of being destroyed in the near future, they should not be altered.

*Example*.—Station "TABLE, 1925" is re-marked in 1940 and one new reference mark established.
The station-mark disk shall be stamped "TABLE, 1925–1940."
The new reference-mark disk shall be stamped "TABLE, No. 3 (or next unused consecutive number), 1925–1940."

*CASE IV*.—The station mark only is moved.

If a station is to be moved, it is generally more practicable to establish a new mark in the new location, and when this is done the old mark must be completely destroyed. The station name shall be preserved but the number "2" shall be stamped after the name (see **2156**). The year the station is moved shall be stamped on the station-mark disk. The date of establishment of the original station shall not be stamped on a new disk, and if the old mark and disk are re-used, the original date shall be effaced by light tapping with the rounded end of a ball-peen hammer and the disk re-stamped with the new year.

At least one new reference mark shall be established, stamped with the new station name and year of moving the station and given the next unused consecutive reference-mark number. The stamping on the previous reference-mark disks shall not be changed.

*Example*.—The station mark for "LUTKE, 1925" is moved in 1940 but the reference marks are not moved.
The disk in the moved mark shall be stamped "LUTKE 2, 1940." If there were two previous reference marks, the new reference mark shall be stamped "LUTKE 2, No. 3, 1940."

*CASE V*.—The station mark and one or more of the reference marks or the azimuth mark are moved.

The station mark shall be treated as in *CASE IV*. The newly established reference-mark disks shall be stamped with the name of the station, the following consecutive numbers, and the year the station was moved. The old date of establishment should not appear on the disks of any of the moved marks. Should it be more practicable to reset one of the moved reference marks rather than establish a new one, the stamping on the disk which is no longer in order shall be effaced as in *CASE IV* and the correct notation re-stamped. The former reference marks which have been moved or destroyed shall be reported as nonexistent.

*Example*.—Station "SITKA, 1925" and its reference mark No. 2 are moved in 1940.
The station-mark disk shall be stamped "SITKA 2, 1940." Reference mark No. 1 shall not be re-stamped. Reference mark No. 2, having been reset in a new location, shall be re-stamped "SITKA 2, No. 3 (or the next unused consecutive number), 1940." Should reference mark No. 2 be destroyed and a new reference mark set, the stamping on the new disk shall be exactly the same as in the preceding sentence. If the azimuth mark is moved it is stamped "SITKA 2, 1940." It is not re-stamped unless it is moved.

*CASE VI.*—The station mark is not re-marked or moved but one or more of the reference marks are moved or one or more new reference marks are added.

The original station name shall be preserved. The number of the reference mark moved shall be canceled and the next consecutive unused number stamped on the disk.

*Example.*—Reference mark No. 2 for "RAVEN 1925" is moved in 1940 but the station mark is not re-marked or moved. The reference mark shall be stamped "RAVEN No. 3 (or next consecutive unused number), 1925." If both reference marks are moved, the new reference marks shall be designated Nos. 3 and 4, or the next consecutive unused numbers, and the year 1925. The same shall apply if one or two new reference marks are established even though the two old reference marks are in good condition and their positions are not disturbed.

*CASE VII.*—The station mark in not re-marked or moved but the azimuth mark is moved.

In this case the azimuth mark shall be stamped with the name of the station, the year of the original establishment, and the year it is moved.

*Example.*—The disk in the azimuth mark for station "MIAMI, 1925" shall be stamped "MIAMI, 1925, Reset 1940."

## 227. Description of Stations

Descriptions of triangulation stations shall be typewritten on Form 525, Description of Triangulation Station, and submitted to the Washington Office in single copy at the close of each season. When typing, it is advisable to make a carbon copy for the party's records and for possible future reference.

Notes pertaining to the description shall be made at the station at the time of establishment or occupation, either in the record book or in a separate notebook carried for that purpose. The complete description shall be written as soon as possible after leaving the station. Do *not* defer writing the descriptions until the end of the season, because the topography at the station sites may not be clearly visualized at that time, resulting in vague and inadequate descriptions.

In writing a description, first enter, at the top of the form, the data relative to the name, State, county, year, reference-mark information, etc., and then write the detailed description. If the space on the card is insufficient, continue the description on another card, but *not* on the back of the same card. When more than one card is used for one description, identify each additional card by the station name at the top, followed by the word "continued" and number the series, "No. 1 of 2 cards," "No. 2 of 2 cards," etc.

In writing the detailed description, begin with a statement showing the class of triangulation used in locating the station, and its general location with reference to some well-known geographic feature, such as a city, town, village, island, cape, or point. Follow with the detailed description and how to reach the station. If the station must be approached by water, emphasize the best place to make a landing and the route to follow to reach the station, should this information be of any advantage. (See also **2142**.) Conclude the description with a line or two concerning each reference mark, giving:

*First,* the general direction (true) each is from the station mark, and

*Second,* a brief description, should there be any essential divergence from the type as indicated by the general *note.*

For standard classification of marks and the appropriate *note* to use in each particular instance, see pages 112 to 114, Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse.

All descriptions of stations established near the shore shall include distances measured from the station, normal to the high-water line, to characteristic and identifiable features of the beach, top of bluff, riverbank, or any other erodable feature, provided the distances do not exceed 200 meters. Since this information is for possible

use in erosion studies, the feature to which the measurement was made must be described in some detail.

A station which is abandoned before its position has been determined, all marks being removed and destroyed, does not require a description.

### *2271. Description of Stations of Other Agencies*

Any existing marked control station or boundary monument, originally established by some other agency, federal or otherwise, whose position is determined by this Bureau for the first time, shall be described as a new station on Form 525. Among the federal agencies, whose stations are most frequently encountered, are the Geological Survey, Corps of Engineers, General Land Office, and International Boundary Commission.

The description shall state clearly whether the existing station was used as a station in the new scheme, or whether a new station was established nearby and the position of the existing station determined by distance and angular measurements. The name of the agency (abbreviated) which established the station shall be placed in parentheses after the name of the station and thereafter shall form an integral part of the station name; e. g., WILKES (U.S.E.). Form 525 must contain a complete description of the station, just as for a new station, since the descriptions of stations established by other agencies are ordinarily not on file in the Washington Office. The description shall state clearly what former marks were found, the stamping or inscription on them, whether the station was reinforced or marked and, if so, how, and what additional reference marks were established. (See **224**.)

### *2272. Recovery Notes*

A report shall be made on Form 526, Recovery Note, Triangulation Station, for each station recovered or searched for. If a station is recovered exactly as previously described and all marks are in good condition and the description is entirely adequate, a statement to that effect will be sufficient on the recovery note. If the station is removed, re-marked, reinforced, reset, replaced, or new reference marks are established, this information, with a brief description of the new mark, reference measurements and directions, and stampings on the marks must be submitted. If the original description is inadequate or changes have taken place since the station was established, such as new roads, real estate development, erection of new structures, changes in property ownership, changes in natural topography due to storms, erosion, excavation, improvements, etc., the recovery note shall contain a complete new description of the station, just as would be written for a new station. A specimen recovery note is given on page 114, Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse.

All reference distances and directions in the original description shall be verified and any discrepancies specifically noted. The initials of the person responsible for the description should appear in the lower right-hand corner of the card.

## 228. PSEUDO-TRIANGULATION METHODS

In a hydrographic survey it is occasionally necessary to determine accurately the positions of one or more stations where conditions preclude the use of the conventional triangulation methods usually described in manuals. Necessity and ingenuity gained through experience will generally produce some substitute method by which

accurate positions may be determined in such cases and often a situation, which at first appears almost insurmountable, may be satisfactorily solved. Generally, stations located by such methods must be considered topographic stations, and marked and described as such, for although the methods often more nearly resemble geodetic methods, usually some phase does not meet one of the requirements for third-order triangulation (see **211**). The few typical substitute methods described here are only illustrative of what may be accomplished in this manner.

### *2281. Location by One Angle and Range*

A station is often needed in a locality where its position may be readily and quickly determined by placing it on range with two existing stations and occupying it to measure the angle between the range and a third existing station.

In figure 8, the old stations MARION, RUDOLF, and DEVON have been previously recovered and signals have been built over them. A station on an island is needed quickly for the control of the topography, when it is discovered that the limits of the topographic sheet are such that a satisfactory topographic position cannot be obtained.

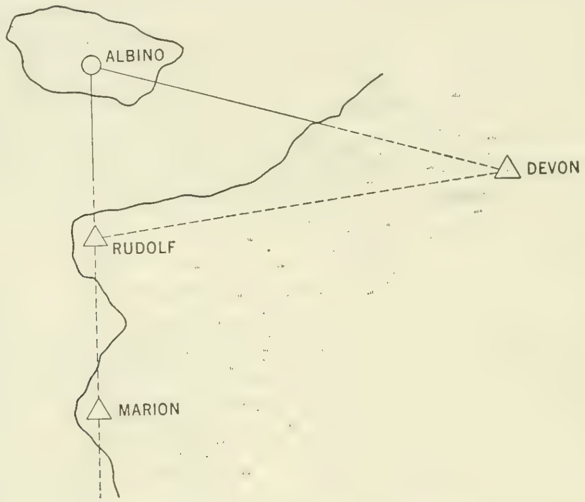


FIGURE 8.—Location by range and one observed angle.

Investigation discloses that a new station ALBINO can be conveniently located on range with RUDOLF and MARION at a point from which DEVON can be seen. This is accomplished by setting up a theodolite on range by eye, and then shifting it slightly until the signal poles at the two stations are precisely on range when viewed through the telescope, their verticality being checked at the same time.

The angle at ALBINO between the range line and station DEVON is measured, this being the only measurement necessary to determine the position of station ALBINO. The angle at RUDOLF is obtained from the forward azimuth of the line to DEVON and the back azimuth of the line to MARION, and the angle at DEVON is concluded to complete the triangle. The position of ALBINO can be computed from the triangle ALBINO—DEVON—RUDOLF or the triangle ALBINO—DEVON—MARION.

If the three old stations have been indisputably recovered (their reference marks having also been recovered and the reference distances checked), no additional check angles need be observed. In this case there is no check on the position, and a station so determined shall be marked with a standard topographic station-mark disk and described on Form 524, Description of Recoverable Hydrographic or Topographic Stations. It is not to be considered a triangulation station since the method does not meet the requirements for third-order triangulation.

If all three recovered triangulation stations had come within the limits of the topographic sheet, a station could have been located graphically by setting up the planetable on the range and resecting on the third station.

### *2282. Ship-Intersection Method*

There are stretches of coastline along which control cannot be established either by triangulation or by traverse, except with extraordinary difficulty and at great expense. Along short sections of such a coast, control can often be established with satisfactory accuracy by the ship-intersection method, provided the stations so located are not used for the extension of control beyond the limited areas in which they occur.

The method is illustrated in figure 9. *A* and *B* are triangulation stations, whose geographic positions are known and which have been indisputably recovered and which are intervisible. To extend control westward along the shore, a new station *C* is selected which is visible from *B* and from which a strategic point farther west can be seen. To locate *C* from the line *AB*, observers must occupy all three shore stations simultaneously. The vessel is anchored at position 1. A black-and-white target on a 2- by 2-inch pole is secured to a stanchion on the flying bridge, or elsewhere, where the target will be distinct and quickly detectable.

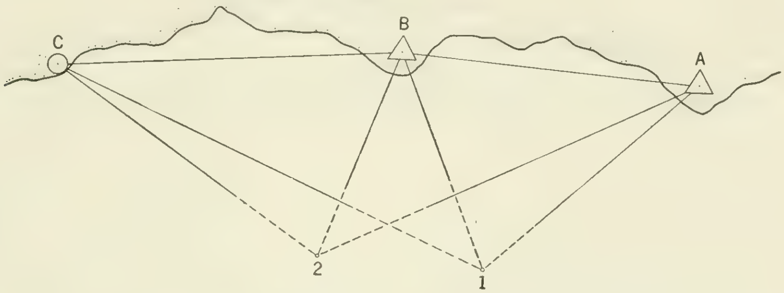


FIGURE 9.—Establishing shore control by the ship-intersection method.

The observing procedure is as follows: Each observer first orients his instrument on the triangulation station immediately adjacent to his station; that is, *A* orients on *B*, *B* on *A*, and *C* on *B*. He then signals to the vessel by a white flag that he is ready to begin observing. When all signals have been received, one long blast is blown on the whistle. This signal is the zero hour and is so recorded by each of the three shore observers, whose watches have been set in agreement within a few seconds. A minute later, a flag is raised on the vessel, where it is visible to the observers, to signify *stand by*. Thirty seconds later, it is rapidly lowered. As soon as the signal flag starts down, simultaneous angle observations are made on the target by the three shore observers. One minute later, the signal flag is again raised for *stand by*, and 30 seconds later it is hauled down for *mark*. This procedure is repeated for direct and reverse pointings for as many positions as required. Six to eight positions with a second-order direction theodolite are considered sufficient.

In addition to the above observations, the observer at *B* must measure the sum angle *ABC* in order to provide data for computing the triangle *CB* 1.

To obtain a length check on the line *BC*, the vessel is moved to position 2 where the procedure is repeated. Best results are obtained when the sea is very calm and there is a minimum of rolling and swinging of the vessel. The same identical part of the pole or target must be pointed on by the three shore observers. Where long lines are to be observed, the observations are facilitated and their simultaneousness is ensured by the use of a sending and receiving radio set at each shore station to maintain communication with the vessel.

The control can be subsequently extended beyond *C* by establishing additional stations and repeating the procedure. At the end of such a scheme, a connection should be made to a line of the scheme of triangulation established by conventional methods, in order to determine the accuracy of the locations and permit adjustment if desired.

The advantage of this method is obvious, for the building of tall signals, the transportation of the necessary lumber, and probable extensive clearing are slow and expensive. Unless the importance of the area is sufficient to require triangulation by

standard methods, it is doubtful if the difference in accuracy obtainable would warrant it, since results approaching third-order accuracy may be obtained by this method.

This type of control does not meet the requirements for third-order triangulation because the ship stations are not stationary and there is one concluded angle in every triangle. Stations located by this method shall be termed topographic stations, and shall be marked by standard topographic-station marks and be described on Form 524. (See **211**.)

### *2283. Buoy-Intersection Method*

A method similar to the ship-intersection method is by the use of a row of buoys, or floating signals, anchored at strategic positions along the coast to form one side of a scheme for a short distance. This method should be resorted to only when the type of coast is such that the positions of the desired stations cannot be determined economically by standard methods and the water is not too deep to prevent anchoring buoys far enough offshore to provide good strength of figures. The buoys shall be placed a sufficient distance offshore so that the smallest distance angle in any triangle shall not be less than 30°.

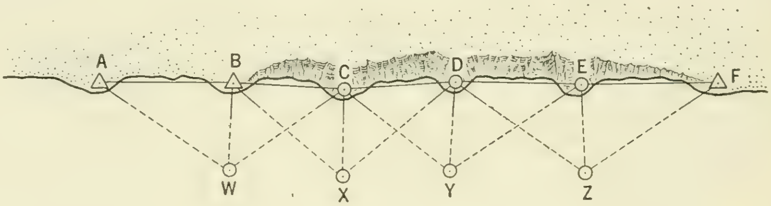


FIGURE 10.—Establishing shore control by the buoy-intersection method.

In figure 10, *A*, *B*, and *F* are established triangulation stations and control is desired between *B* and *F*. Intervisible stations are located at *C*, *D*, and *E* and floating signals are anchored at *W*, *X*, *Y*, and *Z*. The method of observation is apparent from the figure. Enough consecutive stations should be occupied at one time to permit simultaneous observations on any one buoy. Six to eight positions with a second-order direction theodolite should give results approaching third-order accuracy. No length checks are obtained by this method, unless twice as many buoys are used for control (see 2282). A check on the work is obtained, however, when the scheme is closed on *F*. Any discrepancy between the two determinations of *F* should be adjusted and proportioned among stations *C*, *D*, and *E*. If a topographic survey by planetable traverse is contemplated, a field check of the positions will also be obtained as the traverse proceeds from one station to another, the principal check being when the traverse reaches station *F*.

Stations located by this method shall be marked and described as in **2281**.

### *2284. Offset Traverse*

Traverse is not to be considered a satisfactory substitute for triangulation when the location of important control is involved. It may be resorted to, however, in localities where triangulation is impracticable, or along stretches of shore where the principal scheme of triangulation veers inland away from the coast. Complete instructions for third-order traverse may be found in Chapter 4, Special Publication No. 145.

Where the terrain makes both triangulation and traverse by taped distances impossible, a careful offset traverse may be substituted, which will approximate third-order accuracy. A typical area where offset traverse may be advantageously used is illustrated in figure 11.

A scheme of triangulation is impracticable along the shore of the southern end of Onward Island but it can be carried overland, spanning a depression between two divides, to make a connection between the triangulation on the east and west coasts. The coast between *A* and *M* rises abruptly to an elevation of about a thousand feet,

preventing any inland triangulation stations from being visible from the shore. Also the beach is so rocky and the shoreline so indented that measurement by taped distances is impossible but, since the beach is not inaccessible, control for planetable topography can be established by offset traverse.

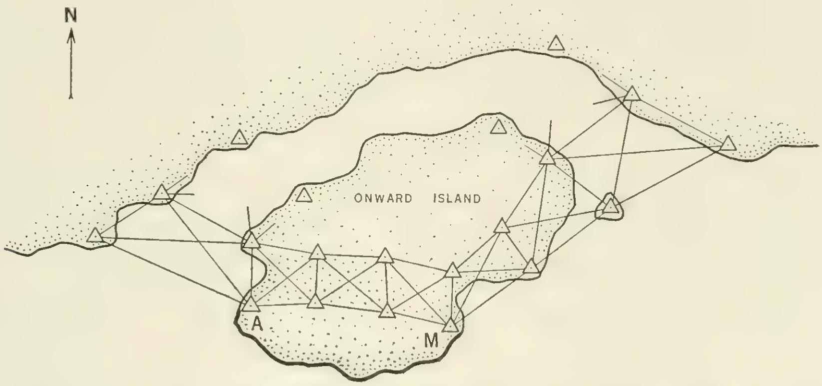


FIGURE 11.—Where offset traverse can be used advantageously along the shore (between $A$ and $M$).

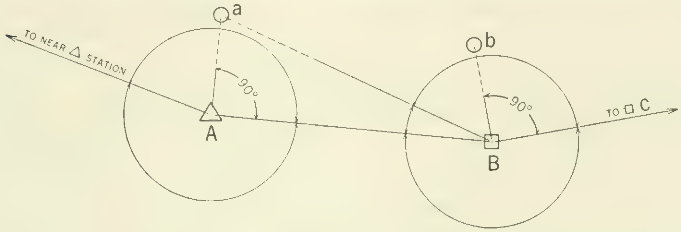


FIGURE 12.—The offset traverse method.

The traverse is run along the outer coast of Onward Island between triangulation stations at $A$ and $M$. The distances between traverse stations are derived from taped offsets and distance angles. Referring to figure 12, triangulation station $A$ is occupied with a theodolite. Any of the other triangulation stations is used for orientation, and a direction angle for azimuth is measured to $B$, the next forward traverse station selected. An offset station $a$ is then established at exactly right angles to the line $AB$ where it will be visible from $B$, and about 30 meters distant from $A$. The angle $aAB$ is then observed and the horizontal distance $Aa$ is taped accurately. Then traverse station $B$ is occupied and directions to $A$, $a$, and $C$ the next forward traverse station are observed. The distance angle $ABa$ combined with the 90° angle at $A$ and the measured distance $Aa$ are the elements needed to compute the slender triangle $AaB$ and to obtain the distance $AB$. At $B$ then an offset station $b$ is selected at exactly right angles to the line $BC$, the angle $bBC$ is observed and the distance $Bb$ measured. The same procedure is followed in occupying subsequent traverse stations. The 90° angles to the offset stations should not be included in the same horizon closure with the other angles, if a repeating theodolite is used.

With offsets always normal to the direction of the forward station, the logarithm of the distance between traverse stations is the difference between the logarithms of the offset distance and the tangent of the distance angle.

If the horizontal distance to an offset station cannot be measured, measure the inclined distance and correct it for inclination. The difference in elevation between a traverse station and its offset station may be determined by bringing the eye in the plane of one station and the visible sea horizon and noting the depression of the other station below the plane on a graduated pole. Another method of obtaining the horizontal distance is to stretch the tape between the horizontal axis of the telescope and the offset station, measuring the inclined distance accurately. Sight the telescope along the tape to the offset station and measure the angle of elevation or depression. From these data the horizontal distance is computed.

The offset traverse method may be expected to result in accumulated errors no greater than 1 meter per mile. Stations located by this method shall be marked and described as in **2281.**

### *2285. Three-Point Fixes*

Infrequently on combined operations and occasionally on air photographic surveys, three-point fixes may be used for locating supplemental control stations in which one or more of the stations observed are intersection points, such as spires, tanks, etc. The observations shall consist of at least one set of 3D and 3R with a 10-second repeating theodolite or two positions with a second-order direction theodolite.

The computation of the three-point problem should be made on Form 655, as described in detail on pages 98 to 100 in Special Publication No. 145, Manual of Second- and Third-Order Triangulation and Traverse. Because there is no check on the position, it is considered a topographic station and shall be marked and described as explained in **2281**.

If observations are made on a fourth station so as to give a check, and all four stations are third-order or better, the supplemental station shall be considered of third-order accuracy, provided the observations consist of at least one set of 6D and 6R with a 10-second repeating theodolite or four positions with a second-order direction theodolite. Standard triangulation station-mark disks shall then be used for marking.

## 23. TOPOGRAPHY

A topographic survey is the determination of the positions, on the earth's surface, of the natural features and the culture of a locality and the delineation of them by means of conventional signs and symbols on a plane surface called a topographic map. Such a map shows both the horizontal distances between the features and their elevations above a certain level called the datum plane. The representation of the variations in elevation is called relief.

Although the depths in the water area are the most important data on a nautical chart, the topographic features of a coast are only second in importance because, in sight of land, the mariner is chiefly guided by, and determines his position from, the aids to navigation and the shore landmarks which he can identify. Contours or form lines must be included so that the topographic relief of the area will permit the mariner to identify quickly and with certainty the rivers, valleys, hills, mountains, etc. A chart should include the topographic details of the adjacent shore and all the salient features of landmark value that are visible from a ship at sea.

Complete instructions and specifications for topographic surveying are contained in Special Publication No. 144, Topographic Manual. Except as modified in the project instructions and in this Manual, those requirements shall be strictly followed by hydrographic parties engaged in topographic surveying. Only the briefest discussion of the subject can be included in this Manual, which is particularly concerned with the establishment of control for hydrographic surveys, and which describes some special applications and methods of planetable and air photographic surveys which are peculiarly adapted to hydrographic surveys.

### 231. General Statement

Topographic control is necessary to supplement the triangulation control for use in launch and visually controlled ship hydrography.

There are two general methods of locating signals for hydrographic control. One method is by planetable, alidade, and stadia rods. This is the older method but is being supplanted to a considerable extent by a new method, namely, air photography. By both methods stations along or just inshore from the beach are located for use as control points for the hydrography. The positions of these stations are plotted on the boat sheet from which the hydrographer determines his position on the water by means of sextant angles observed between three such stations.

When survey parties are engaged in combined operations, the topographic surveys naturally precede the inshore hydrography. The signals, shoreline, and other detail are generally located on aluminum-mounted sheets by conventional topographic methods, and are transferred to the boat sheets in sections as they are completed. In the average area one planetable party can keep well ahead of one launch party sounding with handlead or wire. The recent use of portable graphic-recording echo-sounding instruments has doubled and, in some areas, more than doubled the progress of launch hydrography, and consequently its progress is now dependent to a great extent on the speed at which the topographic parties operate.

### *2311. Reference Plane*

The plane of reference used by the Coast and Geodetic Survey for the elevations and contours for topographic surveys along coastal areas is mean high water (MHW), regardless of locality. It is *never* mean higher high water. The plane of reference for elevations must not be confused with the plane of reference for depths, which is dependent on the locality (see **2172**), or the plane of reference for the control of precise leveling, which is mean sea level.

### *2312. Offshore Details*

The topographer shall locate all rocks, pinnacles, reefs, etc., along the shoreline, if possible. Breakers or sunken rocks, when noted, shall be located approximately, if their positions cannot be determined definitely, so that the hydrographic party may know in advance of the existence of such dangers in order to locate them definitely when working in that area. (See also **363**, **364**, and **365**.)

### *2313. Method of Location*

Except for air photographic surveys, it is assumed that conventional planetable methods will be used to locate the topographic stations, and since a survey by planetable is a graphic survey there are no notes nor record of any of the measurements by which the positions are determined.

When special or unconventional methods are used to locate a station or group of stations in an area, special mention of this shall be made in the Descriptive Report accompanying the topographic survey. If all stations are located by conventional planetable methods, a statement to this effect shall be included in the Descriptive Report.

When a new method is used successfully, a special report shall be made to the Washington Office describing the method in detail with particular emphasis on the probable accuracy obtained by its use.

## 232. ACCURACY OF TOPOGRAPHY

One of the principal objects of the topographic survey is to locate the minor control stations for the sucsequent use of the hydrographic party. Such methods and instru-

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ments shall be used that 90 percent of these control stations will be within 0.5 mm of correct geographic position, and no station shall be in error by more than 0.8 mm.

Except as otherwise provided in the project instructions, topographic surveys (either planetable or air photographic) to locate control stations for hydrography shall be on a scale equal to or larger than the largest-scale hydrographic survey to which they apply.

Planetable traverses, and graphic triangulation by planetable or by means of air photographs, shall start from and end at control stations of third order or higher. Exceptionally, minor control may be extended for short distances up relatively unimportant waterways without ending at a control station of third order or higher, where compliance with the rule would be uneconomic. In such case extraordinary precautions must be taken to ensure the accuracy of the work; the figures in any graphic triangulation must be strong, and the length of sights in any traverse must be neither excessively long nor short, with check distances measured at every traverse set-up.

To attain the required accuracy in planetable and air photographic surveys, the following precautions are essential:

(*a*) Projection lines shall be fine and shall check within 0.15 mm.

(*b*) Basic control stations shall be plotted and checked within 0.15 mm, with reference to the nearest projection lines.

(*c*) Control stations (basic and minor) shall be identified on air photographs within 0.2 mm.

(*d*) Triangles of error at minor control points located shall never exceed 1.0 mm, regardless of the method of location.

(*e*) Closing errors of planetable traverses, prior to adjustment, shall not exceed 0.4 mm per mile, at the scale of the sheet; and in no case shall the total closing error, which may be adjusted, exceed 2.0 mm at the scale of the sheet.

Closing traverse errors within the limits prescribed in (*e*) may be adjusted graphically on the sheet. Traverses resulting in larger closing errors shall be partly or entirely rerun to obtain the prescribed accuracy.

Most planetable traverses are short, since basic control stations are usually only 2 miles apart and never more than 5 miles apart (see **2231**). Aluminum-mounted sheets (see **233**), which are used for practically all planetable surveys, eliminate errors due to distortion. This amount of control and the elimination of distortion make compliance with the requirements relatively easy; in fact most traverse closure errors should not exceed one-half the allowable error.

For planetable surveys, the Descriptive Report shall contain in tabular form a list of all traverses, with their lengths and closures before adjustment, and the names of the control stations at the ends of each traverse.

## 233. Aluminum-Mounted Topographic Sheets

The distortion of the topographic sheet has been one of the most serious handicaps in planetable surveying. Prior to 1932 cloth-mounted Whatman sheets (see **7111**) were used almost exclusively in the Coast and Geodetic Survey for topographic surveys. An aluminum-mounted topographic sheet, designed especially for topographic work, is now being used for practically all planetable surveys. Unless special instructions are issued to the contrary, these aluminum-mounted sheets shall be used for all future planetable topographic and graphic control surveys.

The aluminum-mounted sheet is constructed of highest quality Bristol board mounted on both sides of a flat aluminum sheet 0.04 inch thick. The size commonly used is 24 by 31 inches, which is identical with the size of the planetable board. A metal

clamping device designed in the Bureau is used to hold the sheet rigidly in place while in use. The edges of the Bristol board extend approximately one-half inch beyond the aluminum and are hermetically sealed to exclude any moisture which might destroy the permanent bond between the paper and the aluminum. The Bristol boards on the two sides of the aluminum must be of identical material and quality to preclude a differential expansion or contraction which might warp the sheet. Ordinarily only one side of the sheet is used for the planetable survey although both are sometimes used.

The Bristol board of which the mounted sheets are made has a smooth hard surface which is exceptionally suitable for drafting with either pencil or pen and ink.

The absence of any noticeable distortion under any climatic conditions or over long periods of time makes the use of this sheet a joy to the topographer. A sheet tested in Alaska in 1932 showed no measureable dimensional change. Under the same conditions a Whatman cloth-mounted sheet underwent a percentage change from plus 0.50 percent to minus 0.82 percent.

In 1934 an aluminum-mounted sheet, on which the topographic survey was practically complete, dropped overboard in 8½ fathoms of water. The sheet was retrieved by the topographer by being pierced by nails fastened to the lower end of a 30-pound sounding lead, four nail holes being made in the sheet before it was recovered. It was in the water about 45 minutes. After recovery it was dried carefully, and when the projection was checked it showed practically no measurable change in length and but 0.02 to 0.04 percent contraction in width. Today, in the archives of the Washington Office, this sheet shows no stains nor sign of disintegration and no additional change has occurred in its dimensions.

Actual performance in the field, together with a number of special tests, has proved beyond question that the problem of distortion has been solved by the aluminum-mounted sheet. In 1934 a topographer located a number of beacons by planetable on an aluminum-mounted sheet, scale 1:10,000, and the distances between these were scaled from the topographic sheet at the time. Subsequently, these identical beacons were located by triangulation and a comparison of the computed geodetic distances with the scaled distances disclosed an average difference of only 0.7 meter, the largest difference being 1.6 meters in a distance of 2340 meters. The distances varied from 1164 to 5675 meters.

Other advantages of the aluminum-mounted sheet are that the wind cannot blow between the sheet and the planetable board to disturb the topographer as was the case with the Whatman sheet, and the sheet can be used under adverse climatic conditions, such as exposure to heavy mist or light rain, which made the use of the Whatman sheet impracticable.

It has been proved that a considerably higher accuracy can be attained with the use of the aluminum-mounted sheets and almost every topographer who has used them has expressed pleasure and satisfaction with them. The absence of distortion makes it a pleasure to use the three-point problem without the tedious procedure of adjusting the position for distortion, and careful centering and orientation practically assure that cuts taken to an object will intersect in a point.

### 234. Hydrographic Signals

In the absence of air photographic surveys, the necessary hydrographic control may be located accurately and economically by means of the planetable.

The locating of various hydrographic signals, shoreline, and off-lying detail is of primary importance, as inshore hydrography cannot be done without a large number of temporary signals necessary for sextant fixes close inshore and elsewhere.

When topographic and hydrographic parties are operating in the same immediate area, from the same ship or shore base, the topographer shall daily make a tracing of his results for transfer to the boat sheet, thus providing the hydrographer with the positions of all newly located signals for use in his next day's work.

Since the topographic survey usually immediately precedes and locates control for the hydrographic survey, the topographer must have an intimate knowledge of the requirements of the hydrographer in order to provide him with stations at desirable locations and frequency. The topographer should plan the stations from the point of

view of a hydrographer surveying the adjacent waters from a launch. He should place the temporary signals, whitewashes, banners, tripods, etc., at points best situated to give strong fixes throughout the entire area. If the topographer succeeds in this, excellent control will be available for the hydrographic survey, and the hydrographer will not be delayed by having to build and cut in supplemental signals nor by the difficulty of identifying one signal from another as where they are unnecessarily numerous and similar in appearance.

### *2341. Hydrographic Signal Building*

Stations along a sandy beach or a low flat area should be placed well back from the beach, where practicable, to provide stronger sextant fixes with fewer stations to control the hydrography close to the shore. In any case they should be at least far enough from the beach so they will not be destroyed by wave action due to high water or storms.

Where signals are built along an irregular coast, one should always be located at the head of each inlet or small cove. Stations on cliffs, high hills, or bluffs are unsatisfactory for sextant fixes close inshore, because the sextant may have to be tilted so far from the horizontal plane to measure the angles that corrections have to be applied (see **3338**).

The signals need not be erected with more permanency than is required to remain intact until the hydrography in the area has been completed. Whitewashes, driftwood tripods, flags, banners on stumps, wreckage, and numerous other objects make splendid signals for launch hydrography when properly dressed.

Care must be taken to vary the shapes, sizes, and spacing of the signals to prevent confusion. Too much importance cannot be placed on the spacing of stations, size of the signal, and range of visibility. When viewed from a mile or two offshore, signals spaced too close together, especially if they are small, dim, and of similar appearance, may be difficult to identify when reflected in sextant mirrors.

In the spacing of stations, one every half-mile may be sufficient if they can be located a quarter of a mile inshore from the beach. Where the beach is irregular and vision inland is obstructed by trees, bluffs, cliffs, etc., stations spaced 300 to 400 meters apart will usually be sufficient. Signals widely spaced, unless they are well back from the beach, furnish weak fixes for positions close inshore.

Signals appropriately located and erected are a very important prelude to successful launch hydrography. The ease and smoothness with which a launch unit operates depend to a large extent on the competency with which the signal-building party does its work. Whitewashing or signal building in the fog is unsatisfactory and should not be resorted to; vision is limited and distances cannot be judged correctly, with the result that the stations are frequently too close together and often are all of similar appearance.

Where the stations are located and spaced so that strong fixes will be available at any point in the area and are varied in size and shape so as to be quickly and unmistakably identified, then the control will be adequate for hydrographic surveying.

## 235. Recoverable Topographic Stations

Changes in topography and culture occur as the country develops, or as a particular area increases in importance, and revision surveys become necessary. Such surveys should not be undertaken until a thorough search has been made for stations established

during prior surveys. The number of stations recovered may be sufficient for control of the new survey.

To provide for future use in revision surveys, the topographer shall supplement existing control by establishing additional recoverable stations so that there are control stations at 1-mile intervals along the coastline; except along rugged or swampy coastline bordering areas unfavorable to habitation or industry, where the interval may be increased to not more than 2 miles (see **2141**).

These recoverable stations may be natural or artificial objects when available, or standard topographic disks set especially for this purpose, and together with other control stations provide recoverable control at the required intervals. When practicable, stations should be established where they can be easily identified, and in the most permanent places available. Conspicuous points, rock outcrops, large boulders, etc., are excellent places to set station-mark disks. Often natural or artificial objects exist which make splendid topographic stations that are recoverable without special marking. Some of the natural ones have remained intact for generations and are very likely to remain so for years to come. The establishment of a station at its most likely location will aid a later party in its recovery.

All topographic stations specially marked for future recovery shall be marked with standard bronze topographic station marks, stamped with the name and year. Reference marks are not set at topographic stations. Paragraph 29, page 7, and line 8, page 52 of Special Publication No. 144, Topographic Manual, are hereby amended by the substitution of the word "topographic" for the word "hydrographic." Hydrographic station marks are no longer used by the Coast and Geodetic Survey and henceforth shall be considered obsolete.

### *2351. Descriptions of Recoverable Topographic Stations*

New recoverable topographic stations shall be described on Form 524. Fill in the spaces provided at the top of the form with the appropriate information. Under "Detailed description" write a complete description of the station just as if it were a description of a triangulation station: what it is like; where located; air-line distance and direction from some well-known geographic feature, or some other permanent reference; how to reach the station; etc. (see **227**). Distances and true directions, whether observed by theodolite or compass, shall be given to the high-water line and any nearby witness marks which will assist in the recovery of the station. If there are witness objects or reference points which might be identifiable on air photographs, distances should be measured to several in different directions, and a detailed sketch of the vicinity should be made to show the relation of the station to the witness marks.

The same form shall be used to report the *recovery* of a topographic station, but the following changes should be made:

(*a*) Print a conspicuous capital **R** in the upper right-hand corner of the form.

(*b*) In the space for the year, enter the year of the original marking in parentheses, followed by the year of the recovery.

(*c*) In the space for "Chief of Party," note the initials, in parentheses, of the Chief of Party who established the station, followed by the name of the Chief of Party making the recovery.

(*d*) Under "Detailed description," a brief statement as to the adequacy of the original description will be sufficient if it is adequate. If it is inadequate, write a complete new description just as for a new station. If the station is not recovered, state whether it should be considered *lost* or not, giving particulars, and the time spent in searching for the station.

## 236. Connection With Control of Other Agencies

Permanently marked triangulation and traverse stations established by the United States Corps of Engineers, other agencies, or local engineers, encountered during the normal progress of a topographic survey that have not been connected to the federal network of control established by this Bureau, shall be located by the topographic survey so that their positions are available on the established geodetic datum. Such stations should be located with particular accuracy—locations as follows will be considered satisfactory:

(*a*) By graphic triangulation with a perfect intersection of at least three cuts.

(*b*) By a closed traverse which requires no adjustment—provided that adjusted traverses complying with the requirements may be tolerated in areas where a 5-mile spacing of the triangulation control is permitted (see **2231**).

Permanently marked bench marks, and control stations of other agencies known to have been connected by triangulation to the federal network, but for which the topographer does not have the positions, which are encountered during the topographic survey shall also be located. Bench marks of the first- and second-order level net and tidal bench marks established by this Bureau, as well as bench marks established by the Corps of Engineers, other agencies, and local engineers should be included. No special effort need be made to locate these with an accuracy greater than that ordinarily obtained in the topographic survey.

The triangulation and traverse stations and the bench marks which are located by topography shall be described on Form 524, in accordance with **2351**.

### *2361. Uncontrolled Maps and Blueprints*

Existing maps or blueprints of surveys of special areas may be submitted to supplement topographic surveys or as indicative of changes which have taken place in the areas. In either case a field inspection shall be made on the ground to determine and note which features shown on the plan represent actual conditions; planned improvements or construction, if nonexistent at the time of the inspection, shall be plainly indicated on the copy transmitted. Explanatory notes shall be made wherever necessary for a complete understanding of the conditions at the time of the inspection. The date of the examination shall be noted. No map or blueprint should be submitted in lieu of making a topographic survey unless it complies approximately with the requirements for topographic surveys of this Bureau, taking into consideration the larger scale of the plan. The topographer or Chief of Party shall state over his signature that an examination has been made on the ground, and that the plan, as corrected or amended, represents actual existing conditions at the time.

If the map or sketch is submitted to supplement a topographic survey it should be submitted at the same time and be considered a part of the records accompanying the topographic survey.

Complete details shall be given as to the source of the map or blueprint and if this has an identifying number it should be included; the date of the survey and the scale shall be furnished if known.

Maps and blueprints of surveys of local areas are frequently uncontrolled geographically or are based on a local control which is not connected with the federal network of triangulation. Such a map or blueprint is useless unless a sufficient number of points shown on the map or blueprint are located by triangulation or topography to permit its correlation with the surveys of this Bureau. Three accurately deter-

mined points separated as widely as possible, preferably near the margins of the blueprint or map, and forming a well-shaped triangle, ordinarily will provide excellent control. These points must be tied into the control net by triangulation or located by the topographer at the time of his planetable survey and identified both on the map or blueprint and on the topographic sheet. Features which are to be recommended as landmarks for the use of the navigator are important and shall be located by the topographer independently from the plan.

### 237. Graphic Control Surveys

A graphic control survey is a skeleton survey made by planetable for the purpose of (*a*) locating the hydrographic signals, (*b*) locating additional control for air photographic surveys and clarification of indefinite detail on the photographs, or (*c*) a combination of the two.

Since much of the topography on nautical charts is now obtained from air photographic surveys, graphic control surveys are frequently made in connection with the hydrographic survey. These surveys are usually made on aluminum-mounted sheets (see **233**) which are not subject to distortion and on which the desired control can be located most accurately. Any of the conventional planetable methods may be used.

Such surveys ordinarily do not contain enough topographic detail to be considered topographic surveys and they are not registered as such in the Washington Office.

If a hydrographic survey is made in an area where an air photographic survey is planned in the near future, the graphic control surveys consist almost exclusively of the locations of the hydrographic signals. If the hydrographic survey is made after the photographs are available, but before they have been compiled into planimetric maps, the graphic control surveys may contain, besides hydrographic signals, additional points for controlling the photographs, as well as the delineation of certain indefinite or indistinct features on the photographs. Among the latter are the high-water line along gently sloping sand beaches, intricate waterfront detail, and rocks nearly awash. It may be desirable in some cases to delineate the shoreline in critical areas, as in narrow passages or where channels border the shore closely. Where frequent changes in signals are necessary during the hydrographic survey, the shoreline will often aid in identifying the signals—even a sketched shoreline may be useful in this respect.

Graphic control surveys should also include the location of all aids to navigation within the area which have not been located by triangulation—and cannot be unmistakably identified on the photographs.

### 238. Special Topographic Methods

The use of the planetable and alidade has been found a most efficient and adaptable method of making ground topographic surveys, but in special circumstances the use of a substitute method will be found advantageous, especially in places where the principal aim is to locate stations for the hydrographic control. An experienced topographer will soon learn when and where the use of substitute methods is of advantage or can be tolerated. Generally, any method may be used which will result in accuracy as great as or greater than that obtainable by the usual planetable methods. A method which may result in a lesser accuracy can be tolerated only where conditions practically prohibit the more conventional methods.

### 2381. *Wire Traverse*

Distance measurements by wire, instead of stadia, may be used to advantage in planetable traverse in areas of low flat terrain and sparse vegetation, especially where heat waves are prevalent and are likely to decrease the visibility and the accuracy of stadia distances. Under such conditions wire traverse distance measurements increase the progress of the planetable traverse considerably, not to mention the increased accuracy obtained. This method is very efficient along broad, straight beaches, which are low and flat, where the principal object is to locate hydrographic signals.

Ordinary stranded sounding wire (see **4651**) in a 100-meter length has been found very satisfactory for this purpose. The wire is marked at 25-meter intervals by the insertion of small pieces of cloth between the wire strands. Extra length is allowed at each end of the measuring wire for holding toggles.

Pins about 20 inches long are used for marking the 100-meter lengths on the ground when measuring. A convenient way of accounting for the number of lengths measured is to use six pins. The rear chainman retains one pin at the starting point and the head chainman starts out with the other five. When the latter has used his five pins he has advanced 500 meters. The rear chainman then comes forward and gives the forward chainman five pins and the measurements are resumed. A plus or minus distance at the end of a traverse, or at a signal, is measured with a steel tape and the total distance plotted along the azimuth line drawn on the planetable sheet. The topographer, sighting through the alidade, can keep the chainmen on line by signaling to them with a white flag on a long pole.

Intermediate points may be located along the traverse where necessary for locating detail, the positions of other objects being determined by intersection cuts as the traverse progresses.

A calibrated wire can be used in a similar manner over the surface of the water, to span narrow waterways and to measure from one rocky point to another, if it is equipped at short intervals with fittings to which floats may be attached. It cannot be used where there are crosscurrents. The azimuth can be carried forward with a planetable or a transit.

### 2382. *Sextometer Method*

The *sextometer* method is a substitute for planetable traverse for short distances in unimportant areas where the use of the planetable is impracticable. The survey party operates in a launch, with skiffs for transportation of the rodmen. Azimuth is carried forward by means of angles accurately measured with a navigating sextant. Distance is determined by measuring, also with the navigating sextant, the small horizontal angle between fixed targets on a special rod held horizontally; such angles should be measured to the nearest 10 seconds. The angle may be converted into a distance in meters by means of a hypsograph. (See Special Publication No. 144, pp. 20–23.)

The method is not accurate and is resorted to only to locate the high-water line and hydrographic signals for short distances up minor streams or tributaries, which are too narrow and crooked and where the vegetation along the banks is too dense and overhanging for the planetable to be used economically, and the water beyond is too deep for water set-ups. It is useful in sloughs through swamps and in narrow channels through mangrove growths. The use of the method is authorized only where the waterway is unimportant, its width is less than 200 meters, and a more accurate method would be uneconomic; and for the occasional location of an isolated hydrographic signal. (See also **2462**.)

A sketch of the sextometer rod is shown in figure 13. The rod is 15½ feet in length, with diamond-shaped targets at both ends, whose centers are exactly 15 feet apart. To assist in holding the rod perpendicular to the line of sight from the topographer, a projection of light wood about 2 feet long is constructed perpendicular to the rod at its center. Sights are put on this so that the rodman can assure himself of the perpendicularity of the rod by holding it horizontally at eye level and sighting at the topographer.

The method of use is as follows: The topographer in a launch or boat plots his traverse on the planetable board held on his lap. Beginning at a station of known position, a rodman is sent ahead in a skiff to mark the first station. The topographer measures the orientation angle from some distant signal to the station ahead, and then measures the distance angle between the targets on the 15-foot pole. When its size permits, the distance angle is read *on* and *off* the arc and the two values are averaged to eliminate index correction. The orientation angle is laid off on the planetable sheet by means of a metal three-arm protractor and the position of the station ahead is pricked on this line at the

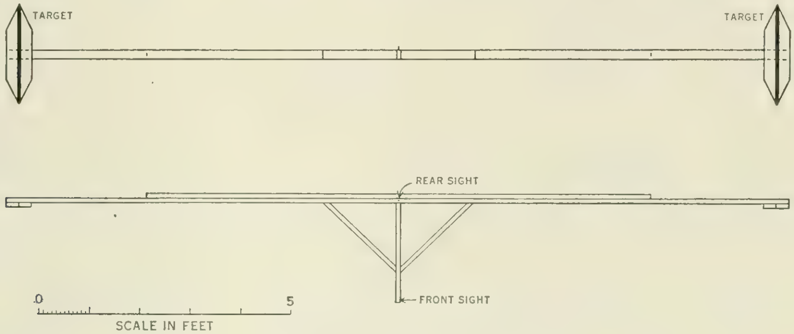


FIGURE 13.—Sextometer rod.

distance obtained by the hypsograph. All orientation and distance angles shall be recorded in order that the graphic traverse may be checked at a future convenient time.

By locating the stations on alternate sides of the waterway, and keeping the distances between stations less than 400 meters, an accuracy closely approaching that obtainable by planetable can be obtained for short distances not exceeding a mile or two. A check should be obtained, where possible, by tying in the end of the traverse to established control stations. Hydrographic signals can be located along the course of the river or stream as desired.

The horizontal angles subtended by the rod may be converted into distances very simply by the use of a hypsograph, or they may be computed from the formula:

$$D'=\frac{L}{2}\cot\frac{\Theta}{2}$$

in which $D'$ = the computed distance in meters; $L$ = the fixed length in meters between the two targets on the pole; and $\Theta$ = the observed sextant angle.

A small correction, always *subtractive* for small angles, must be applied to the computed sextometer distances owing to the fact that the vertex of the small angle measured by the sextant is actually back of the eyepiece of the telescope. The smaller the angle, the larger is the correction. This correction is dependent on the constants of the sextant used and is computed from the formula:

$$\Delta d=\frac{a\sin(\beta+\Theta)}{\sin\Theta}-b$$

in which $\Delta d$ = the correction in meters; $a$ = the distance in meters between the reflecting surfaces of the two sextant mirrors; $b$ = the distance in meters between the horizon mirror and the eyepiece of the telescope; $\beta$ = the fixed angle between the line of sight through the telescope and the line joining the two mirrors; and $\Theta$ = the observed sextant angle.

For a standard Coast and Geodetic Survey navigating sextant, $a$=0.11 meters; $b$=0.20 meters; and $\beta$=30°. Table 4 gives the computed corrections for such a sextant for values of $\Theta$ from 0° to 10°. From these the intermediate corrections may be interpolated with sufficient accuracy. The table also gives the corresponding hypsograph sextometer distances and the corrected distances for a target interval of 15 feet. It is to be noted that the correction is very nearly proportional to the distance, being in this case approximately 1.2 meters per 100 meters of distance. For distances between targets other than 15 feet, a new table of hypsograph and corrected distances must be prepared.

TABLE 4. *Corrections to sextometer distances*

[This table gives the corrections to sextometer distances for a standard Coast and Geodetic Survey navigating sextant, and the corrected distances for a sextometer rod with 15-foot spaced targets. All distances are in meters.]

| Angle $\theta$ | Correction $\Delta d$ | Hypsograph distance $D'$ | Corrected distance $D$ | Angle $\theta$ | Correction $\Delta d$ | Hypsograph distance $D'$ | Corrected distance $D$ |
|---|---|---|---|---|---|---|---|
| 0°00′ | ---------- | ---------- | ---------- | 1°30′ | 2.00 | 174.6 | 172.6 |
| 0 20 | 9.35 | 785.9 | 776.6 | 1 40 | 1.79 | 157.2 | 155.4 |
| 0 25 | 7.46 | 628.7 | 621.2 | 1 50 | 1.61 | 142.9 | 141.3 |
| 0 30 | 6.20 | 523.9 | 517.7 | 2 00 | 1.47 | 131.0 | 129.5 |
| 0 35 | 5.30 | 449.1 | 443.8 | 2 20 | 1.24 | 112.3 | 111.1 |
| 0 40 | 4.62 | 392.9 | 388.3 | 2 40 | 1.08 | 98.2 | 97.1 |
| 0 45 | 4.10 | 349.3 | 345.2 | 3 00 | 0.94 | 87.3 | 86.4 |
| 0 50 | 3.68 | 314.4 | 310.7 | 3 30 | .79 | 74.8 | 74.0 |
| 0 55 | 3.33 | 285.8 | 282.5 | 4 00 | .68 | 65.4 | 64.7 |
| 1 00 | 3.04 | 262.0 | 259.0 | 5 00 | .52 | 52.4 | 51.9 |
| 1 10 | 2.60 | 224.5 | 221.9 | 10 00 | .21 | 25.9 | 25.7 |
| 1 20 | 2.26 | 196.5 | 194.2 | | | | |

## 239. AIR PHOTOGRAPHIC SURVEYS

Air photographs are replacing the planetable as the most efficient means of topographic mapping. The displacements and distortions, which at first limited the use of air photographs to revision of former accurate ground surveys and to the addition of inaccessible detail, have been gradually eliminated by improvements in materials, instruments, and methods. In addition to yielding more complete information at lower costs, modern air photographic surveys now give fully as accurate results with no more control than that required for the planetable. In the Coast and Geodetic Survey, a nine-lens air camera has been developed which gives the high accuracy needed for the location of hydrographic signals with one-half to one-fourth the geodetic control needed for the planetable. The nine-lens composite photographs are 35.4 inches square or 11.2 miles square on a 1:20,000 scale. Each photograph includes an area of 125 square miles at this scale, from 4 to 20 times as much as a single-lens photograph.

### *2391. Air Photographs in Mapping*

Photographs record directions from the position at which they are exposed. A perfectly vertical photograph of perfectly flat land would give map positions directly, but the two conditions are practically never attainable. In a perfectly vertical photograph of land that is not level, only the points vertically below the camera and points in the datum plane will appear in their true map positions (fig. 14). All other points will be displaced radially from the point vertically beneath the lens by distances proportional to their elevations and distances from the plumb point (fig. 15). Note that the trace of the direction from the lens to the object on the plane of the photograph is a line radiating from the principal point. The principal point is the foot of a perpendicular from the rear node of the lens to the plane of the photograph. It is usually marked by a small cross near the center of the photograph or may be found at the intersection of straight lines connecting marks at the middle of the sides or near the corners of the photograph. If the photograph is taken when the camera axis is not vertical, the angles between the radial lines will not be exact; but if the axis is within a degree of the vertical and the elevation differences do not exceed 5 percent of the altitude of the camera, radial lines to control points may be used as a multiple-arm protractor for plotting without graphically appreciable error, the center of the photograph on a

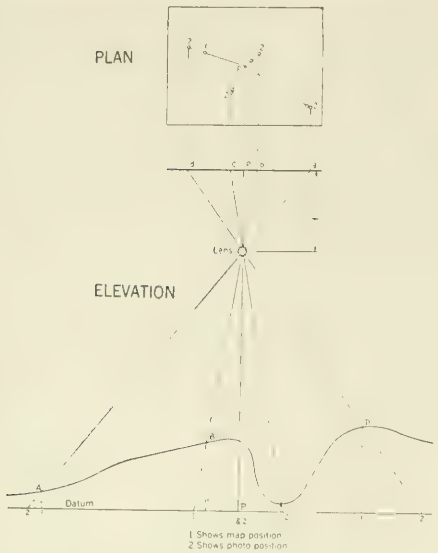


FIGURE 14.—Displacements on air photograph due to relief.

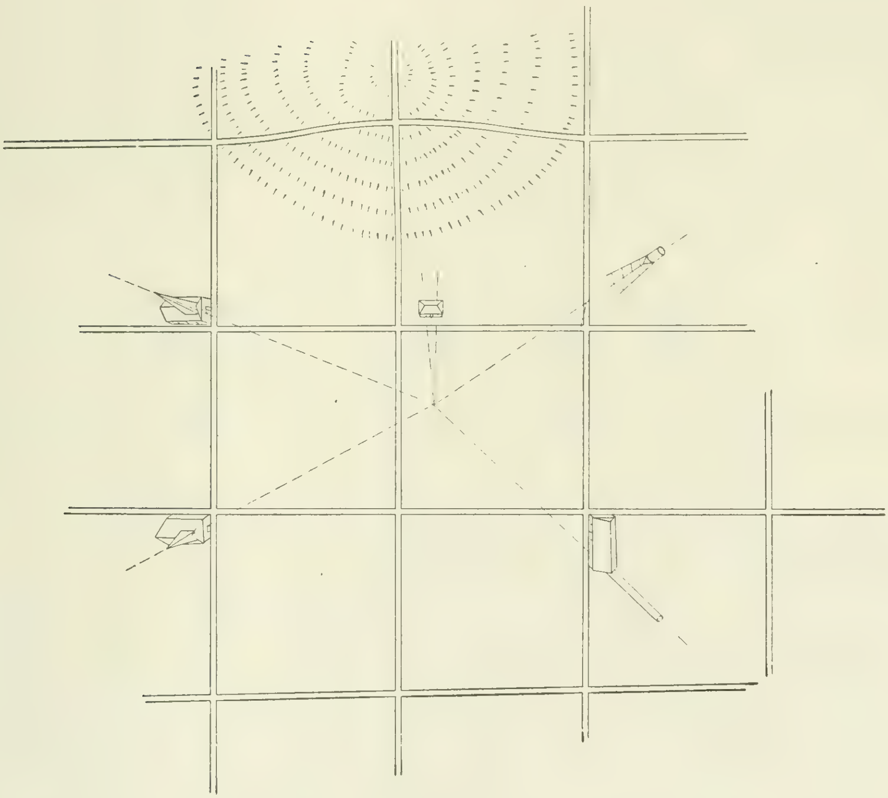

FIGURE 15.—Radial displacement of elevated objects on air photograph. (Note that straight roads passing over hill appear straight when radial but curved when not radial.)

map containing the control points. Radial lines to other objects on the photographs may then be used as *cuts*, intersecting other lines through identical points on overlapping photographs to give true map positions.

In the radial-line method of mapping, the radial lines are traced on celluloid templets. These templets are then adjusted to the ground control stations on a base sheet containing the usual polyconic projection, the radial lines forming a graphic triangulation. Important detail such as control stations for the hydrographic survey, buildings, and road crossings are located by the intersections of their respective radials in the plot. Less important detail is adjusted to position between the intersected points by simple proportion, as when transferring detail between map projections which differ slightly in scale. Care is taken to locate by intersection a sufficient number of points at the changes in slope, so that the correct position of the less important detail will be a simple proportion of the distances between the positions on the map obtained by radial intersection and the distances between the corresponding points on the photograph.

Probably about 80 percent of the photographs taken for mapping fall within the limits of tilt and relief to permit the use of radial lines for graphic plotting without correction. For shoreline and for stations only a short distance above it, the radial lines will be graphically correct for probably 98 percent of mapping photographs, even for tilts of the camera axis up to 3°. An excessively tilted photograph may be recognized by the displacement of images away from its principal point on one side and toward it on the opposite side, as shown by a radial plot or comparison with overlapping photographs. Space is not available in this Manual for a discussion of corrections to radial lines for tilt and relief, or the plotting from oblique photographs. A good text on photogrammetry should be consulted for the method of making such corrections and for descriptions of the many ingenious machines and methods of mapping from photographs (see **9533**).

### *2392. Planimetric Maps*

Most of the air photographic surveying of the Coast and Geodetic Survey has been done in coastal areas of low relief where simple graphic radial-line methods are efficient. The maps compiled have been planimetric only, that is without heights or contours determined from the photographs. The maps show the shoreline and objects visible from the water in full detail, usually on the same scale as the hydrographic surveys of the adjacent waters. Roads, railroads, important public buildings, and other detail for a short distance inshore are also shown. The compilations are made on cellulose acetate at the average scale of the photographs, and are then reproduced at standard scale and printed by photolithography.

When practicable to make the field inspection of the photographs and compile the maps in advance of the hydrography, special prints of the maps are made for the hydrographic party to use for boat sheets and smooth sheets (see **733**). Identifiable objects suitable for hydrographic signals and identifiable locations at which hydrographic signals may be built are marked on the photographs during the field inspection and located by intersection in the radial plot. The positions so obtained are indicated by black circles (2.5 mm in diameter) on the printed maps furnished to the hydrographic party. The limits of shoals and channels which appear in the photographs are indicated by fine dash lines. Much that is irrelevant to the hydrographic survey, such as names and notes in water areas on the printed maps, is deleted during reproduction of the copies for hydrographic use. Generally the boat and smooth sheets made from

air photographic surveys will be accompanied by ozalid prints (see **7332**) containing descriptions of the marks and other data for the location on the ground of the hydrographic signal sites selected by the air photographic party. Prints of the air photographs for field use will also be furnished. (See also **733.**)

When special conditions require that boat sheets be made by the hydrographic party in the field, copies of any photographic surveys available will be furnished with other survey data from the Office.

### *2393. Additional Control Stations*

The number of stations for hydrographic signals located by the air photographic surveys made in advance of the hydrography will vary from practically all that are needed, where plenty of objects of an enduring nature are identifiable on the photographs, as on irregular rocky coasts or in the vicinity of city harbors, to relatively few on straight sand beaches with only featureless detail. Where suitable locations are clearly identifiable at the time the photographs are inspected in the field but are subject to change before the construction of the hydrographic signals, inexpensive concrete marks or stakes will be set by the field inspection party to facilitate exact recovery of the points selected for stations in the photographic plot.

In general, approximately 75 percent of the stations required for hydrographic signals will be located by the radial plot of the air photographic survey. Additional stations must be located by the hydrographic party to supplement these, in order to have sufficient control for the hydrographic survey. Usually these additional stations will not be far from the stations located by the radial plot, and the latter may be used as control or starting points from which to locate the former. Since each additional station ordinarily will be located independently of the others and there are no accumulative errors, unconventional methods will frequently suffice to give sufficiently accurate locations. The methods which may be used to locate additional control and the symbols to be shown on the hydrographic sheets for each method are as follows:

(*a*) Conventional geodetic methods, usually traverse, starting from stations whose positions have been determined by computations, from which the latitude and longitude of the new station can be computed and the position plotted by means of *dms.* and *dps.* (see **7411**). Stations so located are symbolized on the boat and smooth sheets by triangles in red ink (see **743**) if they are of third-order accuracy and by red ink circles, 3 mm in diameter, if of lower accuracy.

(*b*) Planetable traverse, starting at a station located by the radial plot and closing at another similarly located station; or single stadia rod readings from a station located by the radial plot, in which case a closed traverse is not required, but the stadia distance in meters and the azimuth line shall be shown in ink on the boat sheet. All stations located by planetable traverse shall be symbolized by red circles, 3 mm in diameter, on the boat and smooth sheets.

(*c*) Graphic planetable triangulation, using stations located by the radial plot for control. The lines of such triangulation must be kept as short as possible. Stations so located shall be symbolized by red circles on the boat and smooth sheets as in (*b*).

(*d*) Sextant cuts observed at stations located by the radial plot. There shall be at least three cuts to each new station, two of which intersect at an angle of not less than 60°, in order to obtain a strong intersection and a check of the position of each new station. The orientation station used for each cut should be as distant as practicable, preferably twice as far away as the station being located. Stations so located shall be symbolized by red circles on the boat and smooth sheets as in (*b*).

(*e*) Sextant cuts observed simultaneously with three-point sextant fixes from stationary launches, using stations located by the radial plot for control, the new station being determined by three or more well-intersecting cuts. Stations so located shall be symbolized by circles, 3 mm in diameter, in blue ink on the boat and smooth sheets.

(*f*) Combination of methods such as one sextant cut for azimuth, and distance measured by tape, stadia, etc. Stations so located shall be symbolized by blue circles on the boat and smooth sheets as in (*e*).

(*g*) The sextometer method (see **2382**), where the distance to be measured from the station located by the radial plot does not exceed 250 meters. The distance and azimuth shall be shown on the boat sheet as in method (*b*). Stations so located shall be symbolized by blue circles on the boat and smooth sheets as in (*e*).

### *2394. Supplemental Stations*

Infrequently and in extraordinary circumstances, the hydrographer will require supplemental stations which he is not prepared to locate by one of the methods listed in **2393**. These can sometimes be selected from, or located by reference to, the map or photographic detail as described here. All stations so located shall be symbolized by circles, 3 mm in diameter, in green ink on the boat and smooth sheets.

#### A. SELECTED FROM MAP DETAIL

If necessary, points on the planimetric map or boat sheet, which have not been indicated by circles but which are well-defined detail, such as small buildings, dock corners, sharp rocky points, and forks of streams may be used as hydrographic signals. Supplemental stations may be located by reference measurements to such detail, if the objects themselves are not convenient for use as signals or as sites for the erection of signals. Since some of the objects may have been located by proportional adjustment rather than by intersection when the map was compiled, signal location from such detail must be avoided whenever practicable.

#### B. LOCATED FROM PHOTOGRAPHIC DETAIL

If the photographs are available in the field and are of recent date, photographic detail may be identified on the ground at, or near, which signals may be built. Such

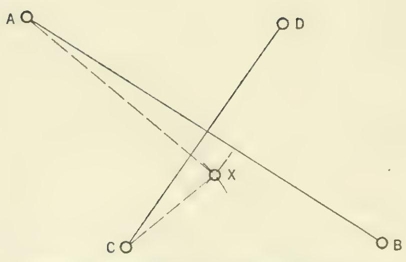


FIGURE 16.—Method of adjusted distances.

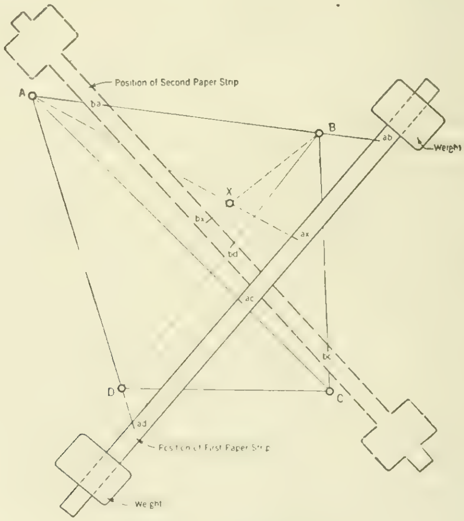


FIGURE 17.—Paper-strip method.

detail may include small detached rocks, ends and forks of small sloughs, intersections of fences or ditches, small clumps of brush, sharp or distinctive points of land or vegetation, and other ground detail which can be located on the photographs within 0.3 to 0.4 mm.

After the selected point on the photograph has been pricked, its position may be transferred to the printed boat sheet by one of the following methods:

(1) *Method of adjusted distances.*—Select two pairs of points, all four of which can be positively identified on the photograph and the printed boat sheet. The lines connecting each pair should intersect approximately at right angles and fairly close to the new station (see fig. 16). The points themselves should be not far from the station and should be in the same plane (not necessarily level) with it. Measure $AB$ and $CD$ on both the photograph and the printed map in order to establish two proportional relationships. Next measure $AX$ on the photograph, correct the measured distance for the relationship in that direction and swing an arc on the printed map. Then repeat the procedure for $CX$ and the intersection of the arcs on the boat sheet will be the location of the new station. Check by arcs from points $B$ and $D$ and adjust proportionally to distance.

(2) *Paper-strip method.*—This method is especially useful for low oblique photographs or photographs whose scales differ considerably from the hydrographic sheet. Select four known points (as $A$, $B$, $C$, and $D$, fig. 17) which can be positively identified on both the photograph and the map or hydrographic sheet, and which are nearly in the same plane (not necessarily level) with the new station. Weight down a paper strip at a convenient place across the photograph, and with a straightedge mark on the edge of the paper strip where radiating lines from one of the known points (as $A$), passing through the other known points and through the new station, meet the edge of the paper strip (*ab, ac, ad, ax*). Then draw lines from point $A$ on the map or sheet through the other known points $B$, $C$, and $D$, continuing them a short distance beyond each point (see fig. 17). Next place the paper strip on the map or sheet and adjust it in position so that the marks on its edge coincide with the corresponding lines on the map or sheet. With the strip in this position draw a line on the map passing through the mark on the paper strip corresponding to the new station (as $AX$). Repeat this procedure using other known points as origins (as $B$, $C$, and $D$, and making marks *ba, bc, bd, bx*, etc.), thus locating the new station by intersection.

(3) *Radial-line method.*—If overlapping vertical photographs are available and a considerable number of points are to be located, a supplemental radial plot should be made. A piece of tracing paper is placed over one of the photographs and fine lines are drawn radiating from the center (principal point) of the photograph through the images of points shown on the sheet and through the new stations whose locations are desired. The tracing is then oriented on the sheet by moving it about until the radial lines corresponding to the known points pass through them. The radial lines to objects whose positions are desired are then transferred to the sheet. This procedure is repeated using the other overlapping photographs. The intersection of the lines to each object, radiating from the centers of the several photographs, is the new position desired.

(4) *Range method.*—It should be kept in mind that any perspective of a straight line is a straight line. Any three objects which are in line with each other in nature (not necessarily at the same height) should be in line on any photograph whether vertical or oblique, and on any map projection used for surveying. Full use of this principle to locate stations or check the accuracy of the surveys should be made whenever practicable.

### *2395. Graphic Control Survey*

If photographic survey data are not available, or if temporary marks for the hydrographic signals are missing throughout an extensive area, a graphic control survey by planetable (see **237**) may be necessary to locate signals for the hydrography. If the project instructions do not specify the amount of shoreline or other topographic detail to be mapped under such conditions, supplemental instructions should be requested.

## 24. SHORE HYDROGRAPHIC STATIONS

A hydrographic station is a definite point on the surface of the earth whose geographic position has been determined by methods ordinarily used only in hydrographic surveys and with an accuracy less than third-order and often less than that of a topographic station. Hydrographic stations on shore are generally located by sextant observations.

### 241. GENERAL STATEMENT

The shore stations used to control a hydrographic survey are ordinarily located by triangulation and topography. One of the purposes of the topographic survey along the coast is to locate the control for the inshore hydrographic survey. It is only occasionally to supplement this control located by triangulation and topography that the hydrographer needs to determine the positions of stations by hydrographic methods.

From the hydrographer's offshore viewpoint a natural or artificial object unnoticed by the topographer may appear particularly desirable for use in controlling the hydrographic survey, and if the topographic survey has been completed it is only by hydrographic methods that its position can be conveniently determined for such use.

In general, hydrographic stations shall not be used as control from which to determine the positions of other hydrographic stations.

Stations located by hydrographic methods shall be symbolized on the boat and smooth sheets by circles in blue ink, 3 mm in diameter.

If a hydrographic station, during or after use as control for the hydrographic survey, is relocated by geodetic or topographic methods it shall be symbolized on the smooth sheet according to the latter more accurate method of location, and so listed in the Sounding Record (see **2154**). Its symbol on the boat sheet need not be changed, but an appropriate note should be made in the Sounding Record or notebook where the cuts obtained by the hydrographic party were recorded that these data have been superseded.

## 242. Frequency of Stations

A sufficient number of hydrographic signals is required so that the hydrographer may determine the position of his vessel at any point in the area of the survey with sufficient accuracy for purposes of charting on the largest-scale published chart and with sufficient accuracy to control the development of any shoals in the area as closely as may be required.

The number of hydrographic stations which may be required depends entirely on the deficiencies in the topographic surveys. If the topographer has provided the control for the inshore hydrography from the viewpoint of the hydrographer and the hydrographic survey follows immediately, the hydrographer should have to locate few, if any, stations.

## 243. Methods of Location

The sextant is the instrument commonly used by a hydrographic party to determine positions and there are three general methods in which this instrument is used to locate hydrographic stations.

Combinations of the methods may be used, of course, when this can be done to advantage and will result in greater accuracy than would be attained by the use of one method alone.

Many of the methods described in section **23**, Topography, may also be used by hydrographers, the stations being classified according to the methods used. Refer particularly to the methods listed in **238** and **2393**.

Shore hydrographic stations shall be located by other methods only in emergencies and as a last resort, when it is impossible to utilize one of the prescribed methods. Stations so located must be kept at a minimum and an effort should be made to locate them subsequently by some more accurate method. For each station so located the method used shall be described and the circumstances explained.

### *2431. Three-Point Fix at Station*

The observer occupies the new station and, with a sextant, measures angles between control stations that will provide a strong three-point fix at the new station. Two angles measured between three control stations appropriately located with reference to the new station (see **333**) will provide the data for the fix. A check angle should always be measured to a fourth station. A navigating sextant should be used for this purpose and wherever practicable the angles should be observed to triangulation stations.

The position of the new station can then be plotted on the boat and smooth sheets by means of a three-arm protractor, or may be computed by the three-point problem

if such accuracy is warranted or if there is much distortion in the boat or smooth sheet. The three-point problem may be computed on Form 655; the method is described in detail on pages 98 to 100 in Special Publication No. 145 (see also **2285**).

### *2432. Station Cut In From Vessel*

The method which is most convenient and which is normally used by the hydrographic party is to fix successive positions of the vessel by three-point sextant fixes, from each of which a simultaneous sextant cut is measured from a control station to the new station. The vessel should be stationary at each three-point fix and preferably at anchor. Accurate results cannot be obtained from a vessel underway. The repetition of each set of observations at a ship station serves as a check on the accuracy and, if the angles observed are interchanged among the observers, serves to verify the identification of the objects.

To measure the necessary sextant angles simultaneously, at least three observers are required; two to measure the angles of the fix, and the other to measure the angle from one of the control stations to the new station or object to be located. The ship or launch positions must be carefully selected so that strong fixes can be obtained and so that the cuts will give a good intersection at the new station. A minimum of three cuts is required, which may be considered sufficient if they intersect in a point when plotted graphically. Additional cuts are desirable. The more nearly the best cuts approach an intersection of 90° the stronger theoretically will be the location of the station, other intermediate cuts serving as checks.

### *2433. Station Cut In From Shore Stations*

A third method which may be used is to occupy three or more control stations with a sextant, observing at each an angle from another control station to the new station. The occupied stations should be selected to provide intersections at the new stations as required in **2432**.

## 244. ACCURACY OF LOCATION

Hydrographic stations located for the control of inshore hydrographic surveys shall be located with an accuracy approaching that required for stations located by topography, since in effect they are to supply deficiencies in the topographic control. For hydrographic stations to be used in controlling the offshore hydrography, a lesser accuracy may be tolerated. In addition to any other requirements, control stations located by any methods whatsoever should be of such an accuracy that no appreciable errors will be projected into the positions of the soundings at the scale on which the work is protracted.

While engaged in sounding, the hydrographer shall watch particularly for any discrepancies in successive positions caused by changes of fix. If such are detected an immediate effort must be made to determine whether or not they are caused by errors in the positions of one or more of the signals used and, if so, to determine which signals. The facts shall be reported immediately to the Chief of Party who shall take such steps as are practicable to verify the locations and relocate such signals as are necessary. If the questionable stations were located from a planetable traverse between control stations, the entire traverse shall be rerun (see **232**).

## 245. Station Marks and Descriptions

Stations located by hydrographic methods shall ordinarily not be permanently marked, but if the frequency of the marked topographic stations is not sufficient for the requirements of **235,** selected hydrographic stations may be marked to supply the deficiency where they are located by methods complying with the requirements for topographic stations. Such stations shall be marked with topographic station marks and be described on Form 524 just as if they were topographic stations (see **235** and **2351**).

## 246. Hydrographic Stations in Inaccessible Places

The framework of a hydrographic survey must be provided by triangulation and usually the control stations for the sounding are accurately located by the topographer, but occasionally the configuration and the character of the coastline prevent the topographic party from landing or traversing along the shore, or from it the main control stations cannot be seen. Under such conditions along unimportant shorelines or waterways the control may often have to be located by less accurate means. The ingenuity of the experienced topographer or the hydrographer will practically always discover a means of locating the control stations needed in such areas by methods sufficiently accurate for the purpose.

Under this heading a few unconventional methods which have been successfully used in the past are described or mentioned merely as a guide to what may be accomplished under such circumstances. The list is not intended to be complete. Such methods should be used only as a last resort.

### *2461. Stations on a Precipitous Shore*

Occasionally a stretch of inaccessible shoreline at the base of steep cliffs is encountered which presents a special problem to the surveyor, especially on open coasts. It is frequently impossible to make landings from small boats at such places or to traverse the shoreline or to see the main control stations from the shore.

In such cases small boats, in periods of flat calm, can generally be maneuvered close enough to the base of the cliffs to place whitewash marks on them by the use of a spray gun or by hurling glass bottles filled with whitewash against the cliffs, which, on breaking, leave the spot whitewashed. The whitewashing should be done at high tide and every effort should be made to place the signals on the cliffs as high above the high-water line as possible in order to prevent their being washed away by the seas before they have been used.

When it is impracticable even to place whitewashes as described above, it is often possible to identify natural objects such as rocks, discolored spots on the cliffs, clumps of bushes, or trees which will serve for signals in lieu of anything more definite.

The whitewashes or natural objects are then cut in by the method described in **2432.** Figure 18 illustrates such a condition and the method used.

Another method of establishing control for the inshore hydrography along an inaccessible coast, provided the depths are not too great, is to anchor a series of buoys comparatively close inshore. These are located in the same manner described above for locating the shore stations. This method is described in **2551.**

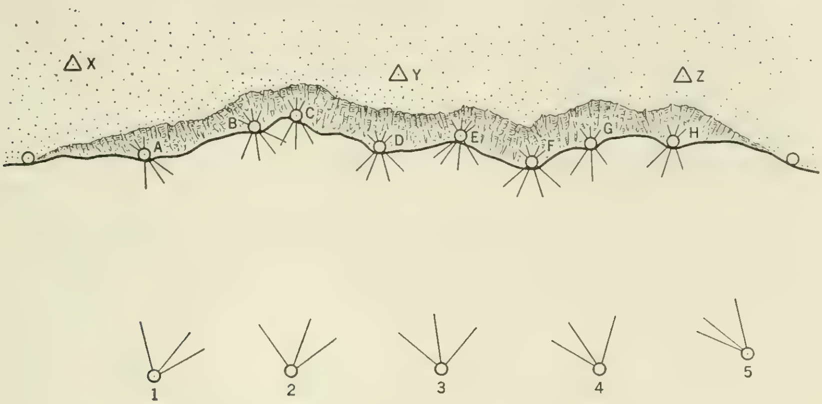


FIGURE 18.—Sextant location of stations along a precipitous shore.

In the figure, the three triangulation stations $X$, $Y$, and $Z$ were established from landward and cannot be seen from the shore immediately below, although they are visible from the water area a short distance offshore. After whitewashes have been placed or other objects selected along the shore, represented by points $A$ to $H$ inclusive, the survey vessel occupies successive ship stations, indicated on the sketch by 1 to 5 inclusive, which are located by three-point fixes observed to the triangulation stations $X$, $Y$, and $Z$. The vessel should preferably be anchored at each station. (See **2432**.) As each successive ship station is located, simultaneous sextant angles are observed to the new stations along the beach. The angles should be measured from an initial station so located that they will be nearly horizontal, and if any of them are inclined appreciably they should be corrected according to **3338**.

If the topography of the shoreline along such a coast cannot be surveyed in any other manner, it may be sketched with reference to the whitewashes or the buoys from a launch or small boat using a sextant to cut in other points.

### *2462. Control in Narrow Unimportant Waterways*

It is frequently impracticable to locate control by conventional methods up narrow unimportant sloughs or creeks, especially where the shores of these are fringed by mangroves or other vegetation which prevents landing on them. Waterways with sufficient depth of water, or important enough to be useful in navigation, require accurate detailed surveys and the control in them must be established by conventional methods regardless of effort or cost. In sloughs through mangroves or in swamps or minor tributaries less than 200 meters in width, where the depth of water is trivial and there is no known navigation of importance, less accurate methods can be tolerated where control by more conventional methods cannot be established economically. If the vegetation on the banks is not too tall it is frequently possible to control the hydrographic survey from a few accurately located points at some distance from the shore, by observations made over the vegetation without the necessity of having control points on the shores themselves. Where the waterway is shut in by trees or other vegetation on both banks so that nothing beyond them can be seen, an awkward problem is presented. One method of locating the control is the sextometer method, described in **2382**.

If the waterway is short and not too narrow the control may be located by a sextant triangulation up the stream. It is rarely possible in such cases to arrange well-conditioned figures and the surveyor must frequently resort to the use of single triangles, often without adequate checks. The signals to be used for control should be built

first. They usually consist merely of small banners tied on the branches of trees or mangroves at points and other places where good views are obtained, and so arranged to form the best figures. In executing the sextant triangulation all triangles should be closed by the observation of all three angles and adjusted for closure. Navigating sextants should be used, but closing errors of several minutes may be expected. If at all practicable the sextant triangulation at its farther end should be joined to control points located by more accurate methods to determine the closing error and provide for an adjustment of the scheme. A geodetic computation of such a scheme is usually unwarranted, but to obtain sufficient accuracy it should be plotted on an aluminum sheet and at a scale several times larger than that of the hydrographic survey of the area.

Sextant triangulation may be advantageously combined with the sextometer method or with distance measurements with a floating calibrated wire, described in **2381**. In any case, advantage should be taken of long vistas to observe directions to stations as far ahead as possible. These will strengthen the azimuth of the scheme appreciably.

## 247. Natural Objects Located From the Vessel

The offshore distance to which hydrography can be controlled visually depends directly on the elevations of mountain peaks, hillocks, and other natural and artificial objects visible from offshore, and the number of these which are located for use as control.

The positions of some of these are determined by triangulation and by topographic methods, but since the perspective is entirely different when viewed from seaward a number of definite points, excellent for use as hydrographic stations, generally remain unlocated. During combined operations the hydrographic party frequently detects these in time to have them located by the topographer or the triangulation party, but when these parties have completed their operations in the area the only recourse, if they are to be available as hydrographic signals, is to locate them by hydrographic methods.

They are usually located from the ship by sextant cuts by the method described in **2432**. Vertical angles to any peaks or hillocks should be observed at each position at which cuts to them are observed. The elevations computed from the vertical angles serve to verify that the cuts have been taken to the same object. (See **382**.)

Since many of the objects useful in controlling offshore hydrography are only visible at a considerable distance offshore, proper identification is one of the important problems of location. Each object should be thoroughly described at the time of the first cut, and a perspective sketch made of the object and its surroundings for use in identification at the time of future cuts. When cuts are taken for the location of natural objects the vessel should be brought to a full stop in the water and anchored if practicable. After the vessel has swung to her anchor a number of cuts can be obtained to be plotted or computed from the same fix if they are taken in rapid succession. Each fix should be verified after the cuts have been taken to ensure that the angles have not changed appreciably. When the vessel is stopped but not anchored, as many observers as practicable should be used so that the angles of the fix and the cuts may be taken simultaneously. At each stop several fixed positions may be required where a number of cuts is to be taken. A check angle should be taken at each position. It is important that the cut be referenced to a control station close to the object, if available; the fix itself need not necessarily include this control station.

If some of the cuts are taken from positions comparatively close inshore, considerable care must be exercised to avoid mistaking shoulders of hills for the hilltops. At the angle from which these are observed a shoulder projecting seaward frequently resembles a hilltop. Hills and peaks located for use as control for the hydrography should be located from the area in which they are to be used; or if greater accuracy of position can be obtained closer inshore, each of the objects should be viewed from various directions throughout the offshore as well as the inshore area to ensure that the top is being viewed from both areas.

Rounded indefinite hilltops should rarely be used as control in hydrographic surveys, but in lieu of better objects they may be used with sufficient accuracy in the offshore area or when combined with two much nearer control stations (see **3336***a*).

In addition to peaks and hilltops other natural objects not noticeable to the topographer along the beach frequently show up very distinctly from considerable distances offshore. Among these are waterfalls, rock slides, scars on hillsides which have been denuded of trees, and discolored spots on cliffs. In populated areas most artificial objects useful as hydrographic stations, such as water tanks, stacks, and conspicuous buildings, will have been located by the topographer. But occasionally there are buildings, lone trees, or clumps of trees, etc., which do not appear distinctive from the topographer's nearer viewpoint but which make excellent hydrographic stations for offshore use.

### 248. Records

All observed data for locating hydrographic stations shall be recorded in a clear and understandable manner with copious explanatory notes, because these data must be used to plot the stations on the smooth sheet by personnel who probably were not present during the field work.

When a number of such stations is located during a hydrographic survey the data shall be recorded in a separate sounding volume or notebook apart from the hydrography. When only a few such stations are located the data may be recorded in the regular Sounding Record, as observed in connection with the hydrographic survey. In case a separate sounding volume or notebook is used, it should be numbered as one of the sounding volumes of the hydrographic survey and forwarded as part of the records of that survey (see **8321**).

When the data are interspersed through the Sounding Records, an index of the stations shall be provided on page 2 of volume No. 1, with references to the volume and page numbers on which are recorded all the data for the location of any given station. When the data are recorded in a separate volume or notebook the index shall be in the front of this.

The cuts should be recorded immediately after the three-point fix position at which they are taken. Each new station to which cuts are taken should be referred to by name in the records and at one place in the records each such station should be described. If it is a natural object the description should be complete enough to ensure its identification during the survey and at future dates.

Recoverable stations shall be described on Form 524 (see **2351**).

## 25. CONTROL BUOYS

A system of accurately located buoys on which three-point fixes can be observed, or to which distances can be measured by radio acoustic methods, furnishes the most economic means of extending accurate hydrographic surveys beyond the limit of

visibility of shore control, or of developing shoal areas out of sight of land. This type of control has increased in importance with the need for carrying surveys farther and farther offshore, and with the necessity for controlling such surveys more accurately than was possible by dead reckoning or astronomic methods. Until recently the areas in which buoy-controlled surveys were practicable were limited by the necessity of anchoring buoys in comparatively shoal depths. The Coast and Geodetic Survey has recently adapted ground tackle equipment for use in deep water. With it buoys have been anchored in depths as great as 1,300 fathoms and the same equipment can probably be used in depths of 2,000 fathoms. (See **2834**.)

In areas of comparatively shoal depths, in which dangers to navigation may exist, a thorough hydrographic development is necessary. In such areas the survey is best controlled by sextant fixes for position determination. Such surveys must be extended a considerable distance offshore along much of the Atlantic Coast and even more extensively in the Gulf of Mexico. In these areas the approved practice is to control the hydrography as far offshore as practicable by sextant fixes on shore objects, and then to establish a system of buoys to which sextant angles are observed to control the remainder of the required survey.

Offshore surveys in areas of moderate depth, beyond the visibility of shore stations or where the development does not require sextant fixes on survey buoys, are controlled by R.A.R. methods or accurate dead reckoning or a combination of the two. A system of buoys may be used in each case to provide greater accuracy and to coordinate the survey as a whole. The buoys may be sono-radio buoys or survey buoys, or both, at stations of known position and at which the dead-reckoning lines are started and ended. Frequently shoals, small or extensive in area, are found far offshore on which close development is required in order to determine the least depths. If the area is extensive, a system of buoys is required to provide the control. If the shoal is small, a single buoy located near its center will suffice if bearings to it can be obtained from any part of the area. If R.A.R. methods can be used, distances obtained from a sono-radio buoy near the center of the shoal, combined with visual bearings, provide an excellent method of developing the area. Short distances to a buoy may be determined from depression angles observed to the waterline of the buoy, provided the height of eye of the observer is appreciable and accurately known (see **3362**).

Other uses of buoys are to extend or supplement shore control. A buoy traverse may be used to carry control along an inaccessible coast where triangulation is impracticable. Buoys may be used to furnish control for inshore hydrographic surveys along a coast where it is impossible to make landings to build and locate shore stations. Also a buoy traverse may be used to extend control across a body of water to an island or shoal area to which it cannot be extended by conventional land methods.

In the establishment of the various systems of buoy control there are many details which are common to several, and to avoid repetition this section treats first of the most simple case, the location of a single buoy, and expands to the most complex, the location of an extensive buoy system by traverse and acoustic distances.

Any system of buoys used for the control of offshore hydrography beyond the visibility of shore stations must be connected with established shore control or located by astronomic observations. A buoy station within the visibility of shore stations may be located almost as accurately as a shore station by various combinations of sextant angles and azimuths. There are various methods of locating a station beyond the visibility of shore stations, the accuracy attained being dependent on the method and instrumental equipment used. The method selected to locate any offshore buoy

station will be dictated by the equipment available, the type of survey, and the desired accuracy of position. In the survey of an offshore area of deep water, a lesser accuracy of location may be tolerated than would be acceptable for a survey of an area of relatively shoal water which may contain dangers to navigation. One should always seek to attain the maximum practicable accuracy of position regardless of the method selected to locate control—judgment and care should be exercised in executing all phases of the procedure.

The choice of a method of location is governed by the following factors: (*a*) Availability of existing shore control, (*b*) depth of water to anchor the buoy, (*c*) purpose or use of the station, (*d*) availability of instrumental equipment, and (*e*) accuracy desired. Irrespective of the method chosen, buoy stations should be selected at positions relative to the shore stations from which they are to be located so that a maximum strength of location will result, taking into consideration the safety of the survey vessel while anchoring and locating the buoy.

The position of a buoy station may be determined from the observed data by graphic methods or by computations. In general, graphic methods furnish the required accuracy for small buoy-control systems, provided accurate methods are used, but it is frequently more desirable and easier to compute positions in the larger systems, particularly in those extending a considerable distance offshore.

The relative advantage of each method of determining positions of buoy stations is discussed in the descriptions of the various methods in **251**, **252**, and **253**. These need not be considered to exclude other methods which might be used or combinations of various methods which may be employed. They are listed in the approximate order of probable accuracy of the resulting position, with the most accurate method first. It so happens that this corresponds in general to the order of simplicity of location and the facility with which the final position is obtained.

### 251. Sextant Location of a Single Buoy

Sextant angles may be used in numerous ways to locate survey buoys and a few of the more common methods are described under the following headings. Sextant angles may also be combined with other observations in locating survey buoys, a few of the methods being described in **252** and **253**. It is good practice to repeat all observations, particularly sextant angles, as a check, and it should be understood that this is required, wherever practicable, although it is not specifically mentioned in each instance. In repeating observations, the interchange of angles among the observers is a good practice to ensure the identification of the objects.

For most precise results all sextant angles should be observed at, or vertically above, the position desired. Manifestly this is often impracticable, but where the observations are made at an eccentric location, the eccentric distance and direction should be noted.

In locating buoys by sextant, each series of angles should be observed simultaneously and, where practicable, the horizon should be closed. Theoretically all of the angles should be observed from the same point, but practically this is not feasible from a ship's bridge. Generally the several observers will station themselves around the periphery of the bridge where nothing will interfere with their view. The result is that the sum of the angles is greater than 360° by a few minutes, generally 6 or 8.

Angles measured by sextant are not precise like angles measured by theodolite, but certain precautions can be taken to increase their accuracy. Each observer should station himself *toward* his angle from a central point on the bridge, the distances of all observers from this point being as nearly equal as practicable. Then when the horizon

is closed and adjusted, all corrections will be subtractive. Theoretically the corrections to the angles, from the horizon closure, should be proportional to the sizes of the angles, but such refinement is rarely warranted.

### *2511. Three-Point Fix at Buoy Anchor*

To locate the anchor position of a buoy, it is usually preferable to observe the three-point fix at the time the buoy is anchored. When this is done, both angles of the three-point fix and a check angle to a fourth station should be observed at the rail of the ship over the point where the anchor is dropped, and the angles should be *marked* when the anchor is released or when it touches the bottom.

Depending on the character of the shore stations and their visibility and distance, the added height of the ship's bridge or crow's nest may be needed from which to observe the shore stations. When angles are measured thus, from a point an appreciable horizontal distance away from the anchor position, it is necessary to measure the eccentric distance and direction between the observers and the point where the anchor is released. With this in view, the observers will, when practicable, take a position near the ship's pelorus or gyro repeater on the wing of the bridge or on line between the pelorus and the point from which the anchor is released. The bearing between these two points is measured simultaneously with the observation of the three-point fix. The distance between them is measured to the nearest meter with a steel tape. If there is an appreciable difference in elevation between the two points it may be necessary to reduce the measured distance to the horizontal. If practicable, the place from which the angles are observed should be selected so as to facilitate the measurement of this distance.

The position of a buoy located by this method may be plotted most easily by the hydrographer. If the angles have been taken from a position vertically above the buoy anchor and the position is to be located graphically, it is only necessary to plot the position with a three-arm protractor on an appropriate sheet. An aluminum or an aluminum-mounted sheet with accurate projection should be used for this purpose (see **713**). When the observations have been made eccentrically, the position may be determined by graphic methods or by computations. If the scale of the sheet is sufficiently large and care is used in plotting, the accuracy of the position determined graphically will approach, if not equal, that of a computed position.

The position may be computed on forms designed for the computation of geodetic positions. Natural objects, and structures such as tanks, lighthouses, and building cupolas, are often more useful than marked triangulation stations when such three-point fixes are required. The geographic position data seldom include all the required information for such objects and it is often necessary to make inverse computations for azimuths and distances between the stations used. These computations should be made on Form 662, Inverse Position Computation, or on Form 27, Position Computation, Third-Order Triangulation. After the azimuths and distances between the respective stations have been computed, the three-point fix is computed on Form 655, Computation of Three-Point Problem. The resulting data are then entered on Form 25, Computation of Triangles, and the triangles are solved. The actual geographic position is computed on Form 27, using the data derived on Forms 662 and 25. Additional information relative to buoy-control computations is given in **94.**

To obtain the position of the buoy anchor, when the observations are eccentric, it is best to compute the position for the three-point fix and then reduce the latter to the anchor position on Form 27, rather than make an eccentric reduction to the observed

angles before Form 655 is employed. In this computation the distance and direction between the observers and the buoy anchor should be used, but the magnetic, or gyro, bearing must be changed to a geodetic azimuth before use.

### *2512. Three-Point Fix at Buoy*

Weather conditions frequently prevent the measurement of the angles desired to fix the position of a buoy at the time it is anchored, and it is generally not expedient to delay the progress of the project by waiting for suitable observing conditions. In such circumstances the buoy is anchored at the desired location and the observations are made at a later date when observing conditions are favorable.

When it is practicable to do so, it is desirable to maneuver the ship alongside the anchored buoy so that the three-point fix observations may be made at that point. This is rarely attempted, except when there is an exceptionally smooth sea and the current is slack, because of the danger of damaging the buoy. To effect this maneuver, the ship is brought alongside the buoy on the down-current side and the sextant angles of the fix and the check angle are observed at the instant the point of observation is adjacent to the buoy. On a ship without a bowsprit, the ship may be maneuvered until the bow almost touches the buoy, even in rough weather. The sextant fix is observed and the ship backed away. The measured distance from the observation station to the bow and the ship's heading are then used for an eccentric reduction.

The direction and velocity of the current must also be noted. The direction is determined with the pelorus and is observed when the ship is directly down current from the buoy, as evidenced by the ripple marks on the surface of the water, or by the direction of the buoy from the relieving drum, if the latter is used. The direction toward which the current is flowing should always be recorded and this is usually the reverse of the observed bearing, since the ship is down current from the buoy. The observed bearing should be corrected by 180° to obtain the direction of the current. At the same time the velocity of the current should be estimated; whether the current is slack, weak, medium, or strong should be sufficient information.

When the three-point fix is observed at the buoy, the anchor position may be computed or plotted graphically, in the manner described in **2511** for an eccentric observation, except that the eccentric distance is determined from the scope of the anchor cable and the direction of the current instead of being measured with a tape. The method of determining the scope correction is described in **943.**

When it is impossible to observe the three-point fix directly adjacent to the buoy position as described above, it is obtained some little distance away from the buoy. The ship is maneuvered close to the buoy on the down-current side so as to bring the point of observation on board directly in line with the direction of the current, as shown by the ripple marks on the surface of the water, or by the direction of the buoy from the relieving drum, and similar observations are obtained. In this instance it will be necessary to measure the additional eccentric distance from the observation station to the buoy by a sextant depression angle (see **3362**), or by a rangefinder. This observation is made at the same time the sextant angles are *marked* so that all are simultaneous.

The anchor position may be computed or plotted graphically, as explained in **2511** for an eccentric observation, but the eccentric distance must be increased by the distance from the observation station to the buoy; the total eccentric distance is the distance from the observation station to the buoy plus the correction for the scope of the anchor cable.

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### *2513. Three-Point Fixes on Range With Shore Stations*

The position of a buoy may be determined by observing three-point fixes at three or more ship stations, each of which is on range with the buoy and a shore station (fig. 19). This method is particularly useful on larger vessels which are difficult to maneuver alongside a buoy to obtain a fix. The position of a buoy so located is easily determined by graphic plotting; it may be computed, but such computations are rather involved.

The shore stations, with which the buoy is to be brought successively on range, must be selected to give the best possible intersections at the buoy. A fix is observed when the ship observation station is exactly on range with the buoy and shore station, at any convenient distance (usually a fourth to a half mile) from the buoy. The fix on each range may be repeated several times, if desired, while steaming slowly directly away from, or toward, the buoy but keeping the observation station exactly on the range. The observers should stand together but, by shifting their position on board, they can keep the point of observation on range as the ship veers across it. In order that the angles will be observed when exactly on range, the observer who is viewing

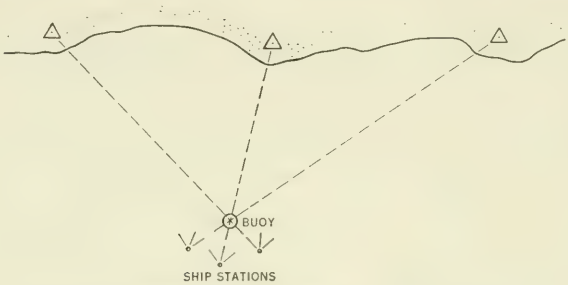


FIGURE 19.—Buoy location from ship stations in range with shore stations.

the buoy direct—not reflected—should give the mark. This is not possible when the buoy is on range with the right object, but in this case the ship is generally far enough from the buoy so that it is possible to view the buoy reflected and thus mark the angles at the proper instant. One observation for the direction and velocity of the current is usually sufficient, but this should be taken immediately before or after the other observations. If the direction of the current is changing rapidly, two observations to determine it should be obtained, one before and one after the angle observations, and the mean of the two should be recorded for the determination of the scope during the period of observation.

The ship positions may be plotted graphically as explained in **2511**. After each fix is plotted, a line is drawn from it toward the shore station which was in range with the buoy. If more than one fix was obtained on a single range, a mean of the resulting lines should be used if they do not coincide exactly, rejecting any questionable fix. If the observations have been accurate, the range lines will intersect at one point which is the position of the buoy. If desired or necessary, the correction for scope of anchor cable may be applied graphically before scaling the position from the sheet.

The computation of such a position is very time consuming. The position of each fix on each range must be computed in the manner described for the computation of the position of the buoy anchor (see **2511**) using Forms 655, 25, and 27. From these computations are derived the azimuths of the ranges, or the azimuths from the buoy to the respective shore stations, and the differences between adjacent

azimuths are the angles at the buoy. With the angles at the buoy known, its position is computed, as previously described, by using Forms 655, 25, and 27. The computation of the anchor position from the buoy position is the same as for an eccentric observation (see **2511**).

It is apparent that the above computations are laborious and they are an unnecessary refinement unless the large scale of the survey requires the additional accuracy. A graphic determination, when the observations have been made in this manner, will result in a buoy position sufficiently accurate for all but thelargest-scale surveys.

### 2514. *Observations Between the Buoy and Shore*

A buoy may be located by sextant at a maximum distance from shore stations by observing three-point fixes at successive ship stations between the shore and the buoy simultaneously with cuts to the buoy (fig. 20). This method of location is particularly adapted to areas where only one line of buoys, parallel to the shore, is required for control (see **2552**).

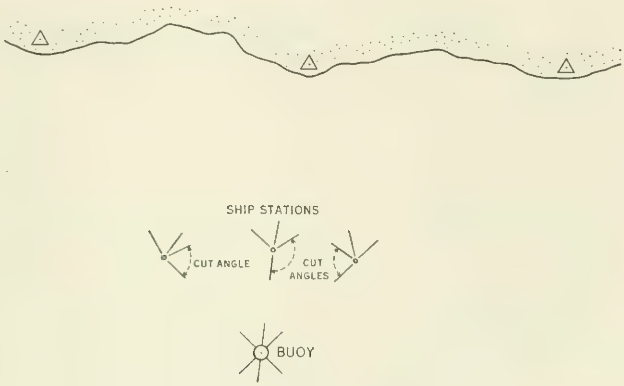


FIGURE 20.—Buoy location by cuts from ship stations.

The method requires unusual care in execution to avoid an uncertain position of the buoy. The successive ship stations should be selected with care, so that the position determinations will be strong (see **3332**) and the cuts to the buoy will intersect at good angles. For best results the angles should be taken so as to close the horizon, wherever possible, and the horizon closure should be adjusted; all angles from each ship station should be measured simultaneously; and the angles at each ship station should be repeated at least once, as a check.

Five observers are required to observe all the angles simultaneously to close the horizon; two for the shore station fix, one for the check angle, one for the cut to the buoy, and one for the angle closing the horizon. One additional observer is required for each additional buoy. If there are not sufficient observers or the angles are too difficult to measure simultaneously, the ship should be anchored for each set of observations.

With the ship drifting, the difference in distance and direction between sets of repeat observations will give valuable information on the velocity and direction of the current for use in reducing a buoy position to its anchor position.

To compute the position of a buoy that has been located in this manner is quite laborious and it is not recommended for general use. The location may be determined graphically with ease and in most cases with an accuracy as great as the method

warrants (see **2513**). Unusual care must be exercised in plotting the positions of the three-point fixes and the respective cuts to the buoy. Three or more cuts will seldom intersect at a point, and considerable judgment is necessary in analyzing them and accepting the most probable position.

### *2515. One Angle at Buoy and One Cut From Three-Point Fix*

A buoy station may be established during hazy weather, with the expectation of determining its position by a sextant fix at the buoy when observing conditions become favorable. When this is attempted, only two of the three necessary shore stations are found to be visible from the buoy station and it is impracticable to move the buoy inshore where all may be seen. In such a case the angle between the two may be measured, and at a point farther inshore, selected to give a good intersection with the locus of the angle obtained at the buoy, a three-point fix is obtained simultaneously with a cut to the buoy (fig. 21). The position of the buoy may be determined from these data.

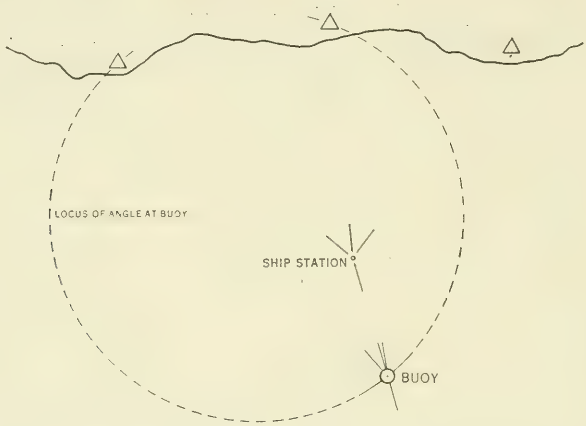


FIGURE 21.—Buoy location by one angle at buoy and one cut from a ship station.

When the observations have been obtained in this manner, the position is best determined graphically (see **2511**). The three-point fix position should be plotted first and the cut drawn at the approximate location of the buoy. The angle at the buoy is next plotted on the direction line with a metal protractor, the center of the protractor being moved along the direction line until the protractor arms intersect the respective shore stations. The center of the protractor will be the position of the buoy. To obtain the position of the buoy anchor, the buoy position must be corrected for the scope determined from the current observation. This may also be done graphically. This correction cannot be made accurately for both observations, since the current at the time of the three-point fix will be unknown, but if the latter is observed immediately after the angle at the buoy, the current may be assumed to be the same for both observations. With these observations only, there will be no check on the location, so care is essential in observing, recording, and plotting the data.

## 252. Directions and Sun Azimuths in Locating a Single Buoy

### *2521. Observations at Shore Stations*

A buoy, if not too distant from the shore, may be located by theodolite or sextant directions measured at shore stations. It may be necessary to start or end a buoy traverse at a point along a coast where sextant angles to three shore stations cannot be observed from the ship, or where the extension of the traverse to a locality where such a fix could be obtained is impracticable. At such places it may be possible to locate a buoy by simultaneous directions from two or more shore stations.

The accurate location of a buoy in this manner is difficult because the directions, measured at widely separated points, must be observed simultaneously; otherwise current data must be obtained which will permit the reduction of the directions to a common point. The most accurate method is for the observers, occupying the two or more shore stations, to mark their directions to the buoy simultaneously at a signal from the ship or by any other means which may be available. The ship assumes a position near the buoy so that the signal to mark may be seen by all the shore observers, but without interfering with the observations on the buoy. The buoy should not be anchored so far offshore that the observations will be too difficult. This is especially important where there are strong currents that may cant the superstructure so that the normally expected visibility is reduced. Before the ship leaves the buoy, the direction and velocity of the current should be observed.

When the observations have been made simultaneously, the position of the buoy is best determined by the usual geodetic computations for the position of an unoccupied station. The buoy position is then reduced to the anchor position from the current information obtained. When shore observations have not been observed simultaneously, each direction should first be reduced for an eccentric observed object on Form 382, Reduction to Center, using the direction and scope of anchor cable data obtained on the ship. The subsequent position computation, made in the usual manner, will be the position of the buoy anchor.

### *2522. Angle at Buoy and Direction From Shore Station*

A special condition arises when only one shore station can be occupied to observe a direction to a buoy, and only one satisfactory angle can be observed at the buoy. This is frequently the case where surf landings are difficult or shore stations are inaccessible and difficult to occupy, and at places where there are insufficient natural objects or structures for a strong sextant fix at the buoy.

The principle by which offshore positions are determined graphically by this method is that a direction from one station to a buoy and the locus of an angle taken at the buoy between two stations will intersect at a point when properly related stations are used in the observations. The theoretical strength of location depends on the angle of intersection of the direction and the locus, and the theoretically strongest location is obtained when they intersect at right angles. In order that they may intersect at or near right angles the shore station, at which the direction is observed, should be selected so that the direction will pass near the center of the circle which is the

locus of the vertex of the sextant angle observed at the buoy (see fig. 22). The site of the buoy should be selected so that a good relation between the shore stations is obtained. The strength of location also depends on the size of the angle at the buoy, a strong location being obtained with an angle of approximately 90°. Angles less than 45° are likely to result in poor positions and should not be used.

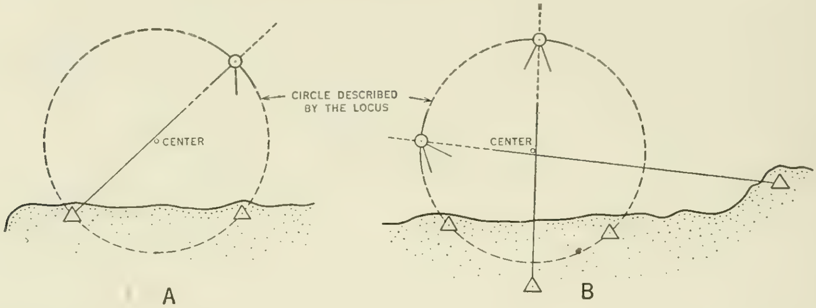


FIGURE 22.—Buoy location by an angle at buoy and a direction from a shore station. *A*. Where one of the shore stations between which the angle at the buoy is measured can be occupied. *B*. Where the occupied shore station is not observed from the buoy.

Two cases involving the above principle may be encountered in practice: (1) Where one of the stations between which the angle at the buoy is measured can be occupied (see *A* in fig. 22), and (2) where the occupied station is not used at the buoy (see *B* in fig. 22). In both cases the direction at the shore station should be observed simultaneously with the angle at the buoy. An observation of the direction and velocity of the current at the buoy should also be made.

The position of the buoy may be determined by computation or by a graphic solution. In (1) the computation is relatively simple, the two observations furnishing sufficient data for the solution of the triangle. The anchor position may be obtained by reducing the buoy position as described in the last paragraph of **2511**. In (2) the computations are involved and laborious and the buoy position is best determined graphically as in **2515**.

If the observations at the buoy and the shore station are not simultaneous, they must be reduced to the anchor position which is common to both. Having the data necessary to compute the eccentric distance and direction, the reduction of the observations may be made on Form 382; the computation being for an eccentric station in the case of the angle at the buoy, and for an eccentric object in the case of the direction from the shore station. After the two observations have been reduced the geographic position of the buoy anchor may be determined as described above.

Where the observation station on board ship is eccentric to the buoy, the reduction may be made by solving the triangle between the observation station, the buoy, and the buoy anchor by computation, or graphically on polar coordinate paper.

### *2523. Sun Azimuth and One Angle*

It may be desirable to obtain all observations on board the ship where there are only two shore stations from which to fix the position of a buoy. It may be impossible to land an observer to measure a direction from shore, as described in **2522**, or inexpedient to do so, especially if the sohre station is inaccessible. Under these conditions the position of the buoy may be determined, as in figure 23, by observing the angle at the buoy and observing a sun azimuth of the direction from the buoy to one of the shore stations (see **4526**).

From these data the position may be computed to obtain a more accurate determination than is possible graphically. The azimuth between the two shore stations is known, or may be computed by an inverse computation (see **2511**). The azimuth between the buoy and one of the shore stations was obtained from a sun-azimuth observation. This latter is corrected by $\Delta\alpha$ plus 180° to obtain the reverse azimuth and the difference between this and the azimuth between the shore stations is the angle

at one of the stations between the buoy and the other station. To obtain the reverse azimuth from the observed azimuth it is necessary to make a preliminary position computation, or make an approximate computation of $\Delta\alpha$ (see **942**). Using this angle and the angle observed at the buoy the triangle may be concluded and the position computation made in the usual manner.

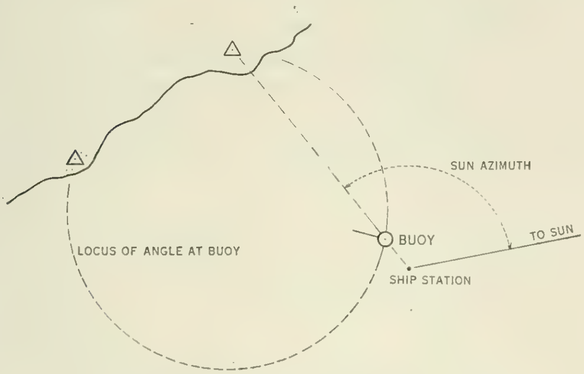


FIGURE 23.—Buoy location from one angle at the buoy and an azimuth to a shore station.

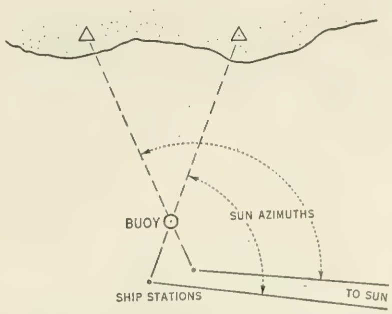


FIGURE 24.—Buoy location by sun azimuths to shore stations.

### *2524. Sun Azimuths From a Buoy to Two Shore Stations*

If two or more shore stations are visible from positions offshore from the buoy and for any reason it is impracticable to observe sextant angles, the buoy may be located by observing sun azimuths from ship stations on range with the buoy and the respective shore stations (fig. 24).

The position of the buoy may be computed when it is determined by this method. The three angles of the triangle may be derived from the observed sun azimuths between the buoy and the two shore stations and the azimuth between the shore stations. The triangle computation and the position computation are made in the standard manner. In taking the differences between the azimuths to obtain the desired angles, the azimuth in the correct direction must be used. When the reverse of one of the observed azimuths is required the observed value must be corrected as explained in **2523**.

### *2525. Sun Azimuth and Distance*

The method of locating one buoy from another by a sun azimuth and distance is the fundamental principle of the system of buoy traverses. There are several ways of measuring distances at sea beyond the sight of shore objects; the most accurate is with the taut-wire apparatus (see **446**), and all long distances between buoys should be measured with it when the apparatus is available.

It is to be noted that the farther apart two intervisible buoys are the more accurately the sun azimuth can be measured, and in a taut-wire sun-azimuth traverse based on a number of intervisible buoys, errors of observation in the sun azimuths tend to compensate. In contrast, any errors in distance measurements are likely to be accumulative.

Other methods of measuring the distance between two buoys are less accurate and should be used with discretion. When one of two buoys is a sono-radio buoy, the distance between them can be measured by subaqueous sound ranging, but this method should be used only where the velocity of sound is accurately known (see **635**).

For supplemental distances in an area where the principal control has been established by more accurate methods, relative distances between buoys may be determined by single or double log runs (see **3374** and **4453**). The accuracy of log distances is definitely limited, and except in emergencies they should be used only to measure relative distances, which may be adjusted to other data.

The azimuth between two intervisible buoys is determined by sun-azimuth observations while on range with the two buoys. The geographic position of one buoy referenced to another is determined by computation on Form 27, using the measured distance and the observed azimuth between buoys, the latter being reduced to geodetic azimuth, that is, to read from the south. The azimuth from the known position to the new buoy must be used. This azimuth is frequently measured in the reverse direction and in such case a correction is necessary (see **2523**).

## 253. Other Methods of Locating a Single Buoy

### *2531. Referencing One Buoy to Another Close By*

When a sono-radio buoy (see **643**) becomes insensitive during use, it is practically impossible to service it in situ, when weather conditions are unfavorable, because of the likelihood of dragging the anchor. In these circumstances it is preferable to anchor a new buoy near the inoperative one and locate the former by a distance and an azimuth from the latter, whose position is known. This method is also used in locating a reference buoy near an isolated sono-radio buoy when there is a possibility of the latter's anchor dragging. The relation between the two may be used later to check their relative positions for any indication of a shift in position. The geographic position of the new buoy is computed on Form 27.

Before referencing one buoy to another, both buoys must have been anchored for sufficient time for the current to affect both buoys similarly; otherwise appreciable inaccuracies will be introduced into the measured distance and bearing.

The azimuth between the two buoys may be determined by several different methods, the choice being dictated by the distance between them, the scale of the survey, the purpose of the determination, the known accuracy of the instrumental equipment, and other factors which might influence the accuracy of the determination. If the two buoys are comparatively close together, a compass or gyro bearing may be sufficient; but if the distance between buoys exceeds three-fourths of a mile, a sun-azimuth determination is preferable. In either case the observed value is reduced to geodetic azimuth.

A short distance between buoys may be determined either by measuring depression angles (see **3362**) or by the use of a rangefinder (see **455**). The shorter distances may be measured more accurately by rangefinder than by depression angles, but only with clear observing conditions, a smooth sea, and, most important of all, an experienced observer. In measuring distances thus, the ship may be placed close to one of the buoys and on range with the other, and angles or distances may be measured to both buoys simultaneously. The distance between buoys is the difference between the two resulting distances.

If the distance between buoys is so great that the data so obtained are not sufficiently accurate, depression angles, or rangefinder distances, to each buoy may be measured from a ship observation station on line midway between the two buoys. There is some difficulty in placing the ship exactly on the range between the two buoys. If there are gyro repeaters on both wings of the bridge, the ship may be maneuvered so that the

bearings to the two buoys will indicate that the ship is on the range. If the azimuth between the buoys has been previously determined, the correct observation station may be found more easily by bringing the proper buoy on this bearing.

### *2532. Taut-Wire Distances From Two Stations*

The location of a buoy beyond the visibility of shore stations, or other buoys, is more difficult, and the corresponding computation or the graphic determination of the buoy position becomes more involved. The preferable method, if the ship is equipped with a taut-wire apparatus, is to measure the taut-wire distances from the buoy, whose position is to be determined, to two or more known positions in sufficiently divergent directions. Such a location has an additional value in R.A.R. surveys, since accurately measured distances, distributed throughout the area of the project, have a supplemental use in the determination of the experimental velocity of sound (see **6352**).

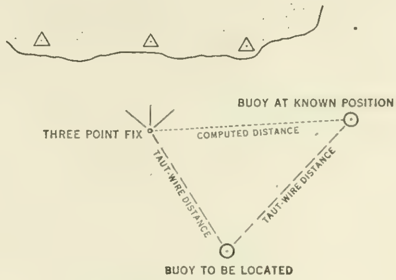


FIGURE 25.—Buoy location by taut-wire distances.

To measure the distance between two buoys by this method, the approximate azimuth between them must be known. The ship proceeds along this course, noting the reading of the registering sheave of the taut-wire apparatus as each buoy is passed abeam, and at the same time the direction and velocity of the current are noted. The direction is observed by compass in the usual manner when the ship is directly down current from the buoy and is recorded in the appropriate space on Form 777, Taut-Wire Traverse Observations. Before determining the geographic position, the measured distance must be corrected for the scope of the anchor cable by using the current observed at each buoy.

Taut-wire measurements may be made between strong three-point fixes, at the approximate limit of visibility of shore stations, and the buoy to be located. The angles determining the inshore positions should be observed from a point near the taut-wire sheave, or else the sheave should be read when the buoy is abeam of the same part of the ship from which the angles were observed.

The position of a buoy from distances measured by taut wire is best determined graphically. This is especially true when the method is employed in combination with locations by subaqueous sound ranging, which are generally determined by graphic methods (see **2533**). The position may be determined by computations if desired. Having two sides of the triangle measured by taut wire, the third side is either known or may be determined by an inverse computation between the two known stations, from which taut-wire distances were measured. A spherical triangle with three sides known may be solved by the use of formulas found in Shortrede's Table of Logarithms.

### *2533. Subaqueous Sound Ranging*

In R.A.R. surveys a buoy is often located by distances obtained by subaqueous sound ranging. The method depends on the presence of accurately located stations, designed for the reception of subaqueous sound, distributed so as to furnish good intersections at the buoy to be located, and furthermore, at unequal distances so that the returns from the stations will not be simultaneous nor indistinguishable on the chronograph tape records (see **6814**). The accuracy of the method depends on the use of the correct velocity of sound through the water, and this, in some localities, is

difficult to determine and, in addition, depends on an accurate measurement of the time element (see **6352** and **685**). Because of the uncertain knowledge of the velocity, distances should be determined from three or more R.A.R. stations and frequently it is necessary to supplement the method by taut-wire measurements.

The time intervals may be measured from a sound originating at the buoy whose position is desired or at three or more stations of known positions. In the former, R.A.R. stations are at the known positions and an ordinary buoy is at the position to be determined and all three distances are measured simultaneously. In the latter, an R.A.R. station is at the position to be determined and time intervals are measured successively at each of the known positions. The latter method is advantageous when two or more stations are to be located, the number that can be located being limited only by the number of returns that can be recorded on a chronograph tape without confusion.

In addition to the above methods, if both are R.A.R. stations the time interval between them may be measured in other ways. The source of the sound may be located at (1) a point directly on line between the two stations or (2) at a point on the extension of the line between stations. The first method is not recommended unless frequent positions of the ship can be determined from other R.A.R. stations to ensure that the ship is kept on the line. It is to be noted also that any error in the ship's run correction is doubled. If the time intervals are so measured the distance between the stations will be derived from the sum of the two time intervals. The second method is not recommended for use unless experience has proved that short acoustic distances may be accurately determined, although it does eliminate any error from the ship's run correction. The acoustic position in the second case will probably be close to one of the R.A.R. stations, and accurate measurement of short distances by acoustic methods has been generally difficult (see **7636***d*). If this method is used the desired time interval between stations will be the difference between the two recorded time intervals. To use either of these methods, fairly accurate dead-reckoning positions of the two stations are required, so the acoustic position may be located as nearly as possible in line with the stations.

In measuring a time interval in order to determine a subaqueous distance, bombs must not be exploded at stations occupied by sono-radio buoys. A bomb explosion near the hydrophone may cause the armature of the electromagnetic unit to become displaced so that it is no longer balanced between the pole pieces (see **6565**) and the unit becomes inoperative. Before bombing at a station occupied by a sono-radio buoy, it must be replaced with an ordinary buoy or, if a relieving buoy is used, the sono-radio buoy must be removed and the bombs exploded at the relieving buoy.

Regardless of the method used to determine the time interval, a series of three to five measurements should be made to provide for the elimination of erratic results. If reliable returns are difficult to obtain from a required station, it may be necessary to obtain a much longer series. A single determination is seldom to be depended on because of the uncertainties in the process. As each measurement is made, the chronograph tape is scaled and the results are tabulated on Form 715, Abstract of Bombed Distances, and compared to ascertain when there is a sufficient number of satisfactory determinations. In these measurements bombs containing the same quantity of explosive should be used for an entire series. A change in the size of bomb will frequently affect the time interval slightly, but enough for the result to appear erratic when compared with the results obtained from bombs of a different size.

The determinations may be made while the ship is lying-to at the proper position, or they may be made while underway. If they are made from the ship lying-to, large

bombs should not be used because of possible damage to the ship's hull. Bombs containing one-quarter pint of TNT have been used while lying-to, without apparent damage to the ship. Larger bombs should be used only while underway.

Acoustic positions are determined underway while steaming on a line between the two R.A.R. stations, or near the station to be located. In the latter case a figure-eight course is steered toward and away from the station, passing it on the down-current side at a distance of 15 to 25 meters and dropping the bomb near the buoy each time the bombing station on board comes abeam of the buoy.

When the data have been obtained by this method, a graphic analysis of the distances is almost mandatory, especially if the velocity of sound is not accurately known or is likely to be variable. In this analysis the distance arcs, determined by multiplying the mean R.A.R. time intervals by the velocity, are plotted with a beam compass on an accurate projection on a nearly distortionless sheet (see **713**). In practice all the distance arcs will rarely intersect at a point, and considerable judgment is necessary in analyzing them before deciding on the most probable location of the station. All other factors being equal, the distances should be weighted according to their relative lengths, the shorter being considered the more accurate. The copies of Form 715 on which the time intervals were recorded should be referred to when determining the relative reliability of the distances. That series of R.A.R. time intervals which shows good agreement should be given more weight than results which are erratic. A study of a series of erratic time intervals will often disclose certain returns which may be rejected to change the mean so that the distance will plot correctly. Such rejections should be made with caution, for a series of time intervals which are in agreement may possibly be in error for some unsuspected reason. This might result in changing the mean of a series of returns to bring it into agreement with an erroneous series, which would result in the selection of an incorrect location.

After the graphic analysis the geographic position of the station may be determined graphically or by computations. The latter is generally not necessary unless the scale of the graphic determination is smaller than that of the survey, in which case there would be a loss in accuracy in transferring the position to the sheet with the larger scale.

### *2534. Subaqueous Distances From Three-Point Fixes*

The position of an R.A.R. station, within sight of shore stations, may be determined by a series of simultaneous three-point sextant fixes and short subaqueous distances at successive positions encircling the station. Four to six sextant fixes should be taken 1½ to 2 miles distant and in different directions from the R.A.R. station so as to furnish a good intersection of distance arcs at the station.

This method is especially useful to locate shore station hydrophones anchored at positions close inshore where strong sextant fixes are not available.

The position of an R.A.R. station so located should be determined by a graphic plot on an aluminum-mounted sheet. Each three-point sextant fix is plotted and from that position as a center the distance arc to the R.A.R. station is drawn after it has been computed from the velocity of sound. The velocity should be based on the surface or near-surface temperature and salinity, for the sound will have traveled this short distance along a direct path near the surface (see **622**). If the correct velocity has been used and all other data are accurate the distance arcs will intersect at a point, which will be the position of the R.A.R. station. If an erroneous velocity has been used the distance arcs will not intersect, but the true position of the station will be

distant from each arc by an amount proportional to its distance from each fixed position. The velocity of sound used should be verified before the proportional method of determining the position is resorted to; any distance arc suspected of being in error should be rejected. The true position of the station is always inside the rough figure formed by the nonintersecting arcs, and if the station is farther from the fixed positions than the arcs are, this is an indication that too low a velocity of sound was used, and if nearer, then too high a velocity was used. (Fig. 26.)

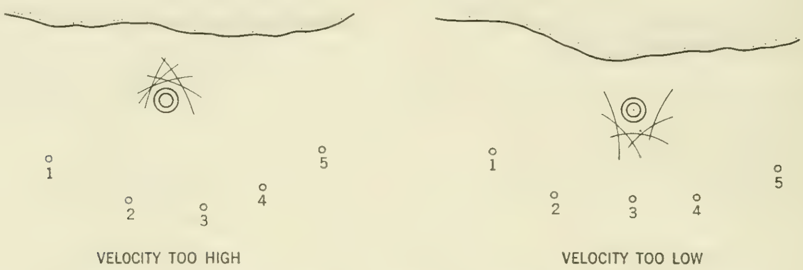


FIGURE 26.—R.A.R. station located by subaqueous distances from three-point fix positions.

### *2535. Astronomic Observations*

Isolated shoals far from shore stations must be surveyed and they often require extensive development but are located where it is impossible to extend shore control to them. Taut-wire traverse, for instance, from the shore control to a shoal area surrounded by extensive areas of deep water would be impracticable. An isolated shoal area in the open ocean far from land is an example. Local control to coordinate the survey is more important than a precise determination of the latitude and longitude of the area. In such areas, where it is impracticable to locate control by other more accurate methods, it may be located by astronomic sights. This method has a rather large probable error, and should be resorted to only when this lesser accuracy can be tolerated.

In order that the position of a station located by astronomic observations may be as accurate as possible, the methods and observations must necessarily be of a higher standard of accuracy than is required in ordinary navigation. The accuracy which can be attained will vary considerably, depending on the conditions at the time the observations are made. Accurate observing under the best conditions should determine the position of a station with a probable error not greater than one-fourth nautical mile. Poor observing conditions will increase the probable error considerably. Under ideal conditions sufficient accuracy will be attained by sets of six observations on four well-distributed celestial bodies taken independently by two or more experienced observers at evening and morning periods of observation. When observing conditions are poor or the observers are inexperienced, the observations should be extended over several days in order to obtain the desired accuracy. To obtain this accuracy, a certain definite procedure must be followed in the selection of stars, observing schedule, and elimination of errors. (See also **3384** and **3387**.)

The best method of locating a station by astronomic observations, where the depth of water permits, is to anchor the ship at the position where the buoy will be anchored later and obtain all observations while at anchor. The ship's heading should be recorded to determine the direction of current at each series of observations. The scope of the anchor chain should be noted for use with the direction of the current in transferring

the observation station on board to the anchor position. The latter will be the station when the observations are completed, at which time a buoy is anchored at the position of the ship's anchor and the ship moves away from the location.

The observations may also be made from an anchorage near the station to be located. In this case the distance and direction between the observation station on board and the buoy should be determined and the scope of the anchor cable of the buoy known. The ship's heading is also required to determine the direction of the current for the reduction of the buoy position to the anchor position (see **943**).

In deep water it is impracticable to anchor the ship in the vicinity of the station and in this case observations must be made while hove-to near the buoy. For each series of observations the necessary data must be obtained to relate the position of the observation station to the position of the buoy anchor.

The necessary astronomic observations are described in **338.**

### *2536. With Reference to Submarine Relief*

A buoy anchored near distinctive submarine relief in an accurately surveyed unchangeable area, at an isolated position far removed from established control, may be located with reference to the submarine relief without other connection to established control. This is accomplished by making a second survey of the immediate vicinity referenced to the buoy, but without regard to datum, and fitting it by means of the bottom contours to the prior survey referred to the standard geographic datum.

This method is of particular value when the survey to be made must be coordinated with the prior survey, and the small amount of additional work required does not justify a long taut-wire traverse from shore stations. It is used where additional development is required on offshore shoals; to extend the original surveys farther offshore; and, infrequently, to start the new season's work of a continuing project of offshore surveys without the delay of extending control from shore stations. The last is frequently of primary importance in R.A.R. surveys because better results are obtained in many areas during the late spring months than during midsummer. With a rapid method of establishing the control, R.A.R. surveys may be executed during the more favorable period, leaving the time-consuming operation of establishing the connection to shore stations for a period when R.A.R. does not function as efficiently.

To fix the position of a station by this method, a well-controlled and adequate prior survey of the area is required, in which a site can be selected which has a characteristic bottom form. Where there is a choice of sites, the control and adequacy of the prior survey should be examined critically and a site selected where the control is strongest and the soundings are most accurate and most numerous. The prior survey should be in sufficient detail so that the depth contours may be drawn with reasonable certainty without plottable errors.

Suitable sites for locations of this nature are limited to areas of characteristic bottom relief in two directions approximately normal to each other so that the position may be fixed in two directions. The submarine feature should be small enough in area so that an extensive hydrographic survey will not be necessary to cover the desired details. The selected site should have sufficient gradient between depth contours so that minor uncertainties in the soundings would cause no appreciable horizontal displacement of the contours.

Not all well-defined accurately surveyed features on the ocean bottom can be utilized for this purpose. Features which are otherwise satisfactory, but which are in changeable areas where bottom shapes may be altered during storms or severe weather

conditions, should be used with extreme caution. Likewise, features that are the result of scouring action of currents and features on banks and shoals, where the existing currents or other conditions are such that there is a probability of change, should be eliminated from consideration.

In an area where the submarine relief is broken and moderately rugged, a station may be located near a locality where the general direction of the depth contours changes (station $A$, fig. 27). The change in direction of the contours should be at least 50° in order to obtain an accurate location in both directions. In an area of similar type a station may be located at a change in bottom gradient where the distance between depth contours changes (station $B$, fig. 27). The accurate position of a station at such

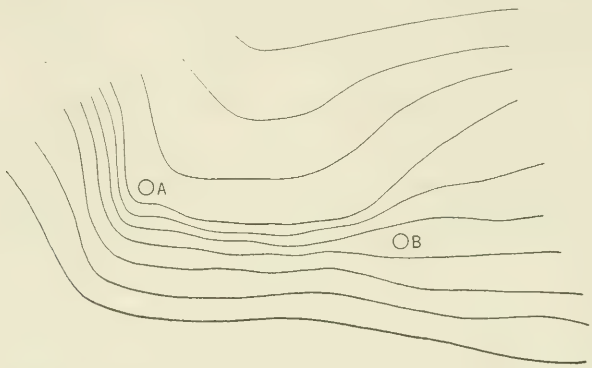


FIGURE 27.—Buoy station located with reference to submarine relief.

a location may be obtained only at a pronounced change in bottom gradient. A station may be established on a shelf near the edge of a valley, to be located in one direction by depth with respect to the depth contours on the shelf and in the other direction by distance from the edge of the valley; provided the axis of the valley is approximately normal to the depth contours on the shelf and provided the depth of water is within the accurate range of the sounding equipment. A site in the vicinity of a small confined crest or small caldron with rather steep sides is generally suitable. If such a feature is small enough, the new survey duplicates the survey of the entire feature and not only fixes the position in each direction but also affords a check on the probable accuracy. Satisfactory sites in a suitable depth of water may generally be found at the upper edge of the continental slope. Irregular submarine features are frequently found there, provided the break of the slope is abrupt.

Before the buoy is anchored, some preliminary sounding lines may be necessary to find the feature, but it will generally suffice to run an accurate dead-reckoning line from a known inshore position across the previously surveyed area on a course so as to traverse the intervening area approximately at right angles to the depth contours. When the required depth is reached, the ship is stopped and the buoy anchored. It will generally be found to be near enough to the submarine feature, but its position will have to be changed if it is not.

If the survey of the features to which the buoy is to be referenced is extensive, a line of buoys may be required which are accurately referenced to one another by traverse methods (see **2525**). The soundings may then be located with reference to the buoys by sextant or by R.A.R. methods. Such a survey is without datum, the stations being merely plotted accurately with reference to one another by graphic methods with only

an azimuth line on the sheet. It is essential that the survey be well controlled in azimuth as it will be held in azimuth when it is fitted to the prior survey.

The sounding lines of the survey to locate the buoy should duplicate the sounding lines of the prior survey insofar as practicable. This cannot be done exactly because the datum is not known at the time. The lines should follow the same pattern, however, and the area should be surveyed in approximately the same detail so that the features may be delineated on both surveys with about the same accuracy. Frequently, additional sounding lines will be required to develop certain features appearing on the prior survey that have been missed by the systematic lines of the new survey.

For greater accuracy, the soundings taken to locate the station should be plotted on a scale larger than that of the future survey for which it is to be used, so that it is frequently necessary to enlarge the prior survey. The required part of the smooth sheet of the prior survey will usually be enlarged photographically to the desired scale at the Washington Office upon request. The soundings should be transferred accurately from it to an accurate projection, preferably on an aluminum-mounted sheet, and closely spaced depth contours should be carefully drawn at the selected location. A knowledge of submarine relief is required (see **353** and **7762**) and the contours should be delineated by the most experienced member of the party. The interval to be used between depth contours depends on the gradient of the bottom relief and the distinctiveness of the feature. It should be close enough to leave no doubt as to the exact form of the feature but not so close that confusion will result when the two surveys are superimposed.

The soundings of the new survey should be carefully plotted with reference to the station to be located at the enlarged scale chosen. They may be plotted on tracing paper but celluloid is preferable because of its greater transparency and dimensional stability. The positions and soundings are plotted with the utmost accuracy by the usual method for this type of survey. The soundings should be reduced to the plane of reference of the prior survey. After they have been plotted, depth contours are drawn on this survey, comparable in all respects to those drawn on the enlarged copy of the prior survey, using the same care.

If the bottom feature selected is adequate for the purpose, little difficulty will be experienced in correlating the two surveys, when superimposed. The two surveys must be maintained in relative azimuth while they are adjusted until the depth curves and soundings are in the best attainable agreement. Perfect agreement is seldom possible from the very nature of the case. It is frequently necessary to effect a compromise adjustment that satisfies, as nearly as possible, all detail represented. To attain this requires painstaking and thoughtful consideration of all the factors involved if the position is to be sufficiently accurate. When the best adjustment has been attained, the position of the station is pricked through the transparency to the underlying sheet and the position scaled in the usual manner.

The accuracy of the method depends primarily on the selection of suitable submarine relief, and secondarily on accurate determination of the positions and soundings, and comparable reduction of the soundings of both surveys. The smooth plot and the selection and delineation of depth contours of both surveys must likewise be of comparable accuracy. If all phases of the operation have been performed with care, the relative position of the station should be adequately accurate for use at the usual scale of offshore surveys.

Small distinctive features near the offshore limits of the area of a season's field work should be developed intensely with a view of possible future use as definite recoverable locations from which hydrographic surveys may be extended.

## 254. Planning Buoy Control

Buoy stations are established for use in controlling the subsequent hydrographic survey, and a buoy system must be planned not only to serve this purpose conveniently and adequately but so that the buoys can be accurately and economically located. The first consideration is how the buoys are to be used to control the hydrographic survey. On this depends to a large extent the choice of type of buoy structure and anchor gear, the general method of anchoring, the distance between adjacent buoy stations in line and the spacing of adjacent lines, and the accuracy of position determination.

From the increased use of buoys to control offshore surveys a number of schemes have evolved, each adapted to the particular conditions encountered. The use of taut-wire measuring apparatus has resulted in greater accuracy in this type of control and has made the use of buoy schemes feasible for the extension of control where it was otherwise impossible.

While it is recognized that each project presents its individual problems and no definite requirements can be stated which are applicable to all, a general discussion of the subject and an outline of the methods that have proved satisfactory should be helpful in all projects. Conditions to be particularly considered are the depth of water, the character and general configuration of the bottom, the average visibility for the season of the year in which the work is done, the maximum currents to be encountered, the frequency of severe storms; and, if R.A.R. is to be used, the conditions affecting the transmission of sound in sea water.

### *2541. Spacing of Buoys in Line*

The distance between adjacent buoys in a line of buoy stations depends on the prevailing visibility, the size of the buoy superstructures, and the purpose for which the buoys are to be used. In general it is better to underspace rather than overspace buoys. The delay incurred in anchoring and picking up a few extra buoys while engaged on this class of work is usually less than that caused by inability to obtain azimuths when needed.

If the line of buoys is solely for the purpose of carrying control by traverse to an offshore area to be surveyed, the buoys may be spaced at approximately a mile less than the limit of average visibility of a buoy in that locality. Except in areas where stable, clear atmospheric conditions prevail, the maximum limit between buoys is not recommended, because of the difficulty and consequently the delay, often serious, in measuring the azimuths between them during less than perfect visibility. Buoys should never be spaced so far apart that there will be difficulty in seeing the far buoy when azimuths are observed. In areas where exceptionally clear atmospheric conditions prevail, 10 nautical miles is a suitable maximum distance between adjacent buoys, provided the observers may occupy an observing station of sufficient elevation.

The theoretical distance that a buoy of a certain height above the water surface may be seen from an observing station on a vessel may be calculated with the aid of Table 8, Distance of Visibility of Objects at Sea, in the American Practical Navigator (Bowditch). To find the distance from which a buoy may be seen, the distance given

in the table corresponding to the height of the buoy should be added to that corresponding to the height of the observer's eye. This distance may be materially reduced by the cant of the buoy structure or by the height of waves on the horizon. Where the atmosphere is slightly hazy, 5 nautical miles should be considered the maximum, and a comparatively clear day will be required to obtain the azimuths at this distance.

Buoys to be used as control stations for three-point sextant fixes may be located 5 nautical miles apart in areas where excellent visibility is prevalent but at no more than 2½ to 3 nautical mile intervals where slightly hazy atmosphere is to be expected. In general, buoys used for this purpose should never be spaced so close as to cause confusion and be mistaken for one another; neither should they be spaced so far apart that fixes will be difficult to obtain.

Adequate R.A.R. control requires that each position be determined from at least three distance arcs intersecting at good angles with one another, and sono-radio buoys should be spaced in line with the expectation that they will provide such results throughout the area of the survey. The spacing will depend, therefore, directly on the efficiency of the R.A.R. equipment and the distance that reliable returns are obtainable.

When sono-radio buoys are to be located by subaqueous distances only, they should be spaced well within the limits of reliable returns in order that their positions may be determined from unquestionable data.

### *2542. Spacing Buoy Lines*

The space between adjacent lines of buoy stations, which are to be used for sextant fixes, depends on the average visibility in the locality. They must be spaced to provide visible control for the area to be surveyed, and usually a spacing one and two-thirds the average visibility will give satisfactory results. The spacing also depends on the size of buoy structure used; a larger buoy with a larger banner or flag will, of course, be visible farther than smaller buoys, especially through an exceptionally clear atmosphere.

A slightly wider spacing may be tolerated when the sounding lines are to be run normal to the direction of the buoy lines. The wider spacing is warranted only when the area being surveyed is not likely to contain critical features and less rigid control is permissible.

### *2543. Direction of Lines*

A scheme of buoy control to be located by taut-wire sun-azimuth traverse must be planned so that the direction of buoy lines permits the observation of sun azimuths between the adjacent buoys. If the azimuth of the line of buoys is in the general direction of the sun at sunrise or sunset, inaccurate azimuths will result because the inclined angle measured in one direction will be too near verticality and in the other direction will be too large. In emergencies, it is sometimes possible to *split* the large inclined angle by measuring an inclined angle to an intermediate object and a horizontal angle from it to the buoy range, but the method is generally unsatisfactory. A floating object or vessel is rarely to be seen in the required direction at the proper time, and to anchor a special buoy for this purpose only is an uneconomic expenditure of time and effort. (See **4523.**) The sun's declination, the latitude of the buoy line, and time of observation are, of course, the three factors that must be considered when planning the direction of buoy lines. During the summer months along the coasts of the United States the azimuths should be measured in early morning or late afternoon when the sun's altitude is not too high. Since the sun is near the prime vertical at these times,

east-west buoy lines are to be avoided wherever possible; north-south lines are to be preferred. In a latitude and at a time of year when the sun's azimuth changes appreciably without its reaching too great an altitude, azimuths may be observed at any time during the day except near noon, and the direction of the buoy line is not so important.

If practicable, the azimuth of buoy lines should be planned so that the inclined angle may be measured by looking at the buoy direct and reflecting the sun's image. The methods of observing inclined angles are discussed in **4526** and reference should be made to this item so that buoy lines may be planned to facilitate observing the azimuths.

### *2544. Buoy-Control Schemes*

Survey buoys used as control for an offshore hydrographic survey are usually anchored in lines throughout the area and oriented so they may be located in the most accurate, effective, and economic manner. A buoy scheme must be arranged so that each buoy station can be accurately located and that a maximum relative accuracy can be obtained throughout the scheme. Since this type of control is comparatively expensive, no more buoy stations should be used than are needed to control the hydrography and the development of an area adequately by the selected method.

A buoy scheme should be planned which will provide effective control throughout the area to be surveyed according to the method to be used and the accuracy to be attained. Schemes of buoy stations depend also on the type, scale, and purpose of the survey, and on the physical characteristics of the area, which differ with each project. A scheme particularly adapted for the control of one area may be entirely unsuitable for another of different character. A system of control for the survey of an area from shoal water to deep water on the East Coast Continental Shelf would probably not be satisfactory to control the survey of an extensive and critical area of shoal water. The latter area would require closer development than the former and a scheme of closely spaced buoy lines would be necessary. Similarly, where some uncertainty in the positions of the control stations can be tolerated, there is a wider choice of method of location which, in turn, extends the choice of a scheme of control. The size of the area, the depth of water, the character of the bottom relief, the required accuracy, and the instrumental equipment available are the principal controlling factors governing the choice of a buoy scheme.

Typical schemes of buoy control which may be employed either as control for hydrographic surveys or to extend control to isolated localities are described in **255**, **256**, and **257**. Combinations of the different schemes may often be effectively employed in the establishment of buoy control for extensive hydrographic surveys.

### *2545. Buoy Structures and Ground Tackle*

The selection of an adequate type of buoy structure and ground tackle of satisfactory weight and strength is of utmost importance when preliminary plans for a system of buoy control are made. The choice of a buoy structure should be made with a thorough knowledge of the area to be surveyed, so that a buoy of sufficient size may be selected for visibility and to support the suspended anchor cable, and the counterweight required to keep it upright against the wind and water currents. The different types of buoy structures are described in **281**, **282**, and **284**.

The anchor cable used to anchor buoys should be strong enough to withstand any reasonable strain to which it may be subjected, but it should not be of such heavy

material that an excessive buoyancy is required to sustain its weight. The anchor cables that have been used with success in the past are described in **283**.

Anchors should be of a type and weight to maintain their positions without dragging against any strain of the anchor cable, but they should not be too heavy for ready handling in anchoring and hoisting aboard. On good holding bottom, lighter anchors may be used than on poor holding bottom. A small concentrated weight of high specific gravity, such as a railroad car coupler, is to be preferred to a large bulky concrete block. The couplers are more easily stowed on board ship and require less space. The types of anchors that have been used with satisfactory results are discussed in **2831**.

### *2546. Buoy Usage*

When buoys are to be used for the control of an extensive hydrographic survey, the work must be planned so that a section at a time can be completely surveyed and fully developed as the control is carried forward. This requires a minimum total number of buoys, a minimum number at anchor at one time, and the buoys are left on their stations for only short periods before being brought on board where any damage or deterioration can be detected and repaired. It is inadvisable to have a large number of buoys at anchor to furnish control for a long period of time because of the risk of the positions being lost by parting of the anchor cable from deterioration or during severe storms. The limited space on board for stowage frequently limits the number of buoy structures to those required for control in an area which can be surveyed in about 2 weeks. The general plan should be to establish the control in an area which can be expected to be completed during the period between trips to port.

Where buoys are located by traverse, it is not necessary that the entire traverse be completed, closed, and adjusted before the buoy positions are usable. This may be done in sections, each section providing sufficient control for each trip in the field, the preliminary unadjusted positions sufficing for plotting on the boat sheet. A sufficient number of buoys should be anchored and located at the beginning of a trip, and at the end of the trip all those no longer needed for control or for the extension of the traverse should be picked up and stowed on deck. This not only eliminates the possibility of loss of buoys while the ship is in port, but also affords an opportunity for repairs to the structures. If the progress of the survey is away from the base, another advantage is that buoys may be anchored en route to the working ground and weighed while en route to port.

When R.A.R. control is used, the areas are generally too extensive to be completed in one trip but it should be possible to follow the same general plan, except that the buoys are left in position for two trips in the field instead of only one.

In general, buoys should not be left in the water for more than 6 weeks or 2 months at a time. Salt water soon corrodes ordinary wire rope and, if left for a longer period, the loss of the buoy and anchor is risked by parting of the wire. When a buoy position is required for longer periods, it should be referenced, at the end of 2 months, by anchoring another buoy nearby, which is located by reference to the original (see **2531**). The new buoy position may then serve in lieu of the original position in the event that the buoy at the latter is lost.

Sono-radio buoys are generally visited more frequently than ordinary buoys, to renew batteries and to service the R.A.R. units, and more opportunity is afforded to inspect the condition of at least the upper part of the anchor cable. Because of its

cost, it is advisable to replace a sono-radio buoy with an ordinary buoy structure during extensive periods in port, especially during stormy seasons of the year.

## 255. Buoy-Control Schemes for Location by Sextant

### *2551. Buoys for Control of Inshore Hydrography*

Along precipitous shores where it is impossible, for any reason, to build or locate shore stations adjacent to the water, a line of buoys may be anchored offshore and used to control the inshore hydrography between them and the coastline. Control established in this manner is especially useful in localities where rugged interior topography prevents the establishment of triangulation stations on the shoreline, and along beachless coastlines where planetable traverse is impossible or where boat landings to build signals can be made only with great difficulty. To locate these buoy stations, established control stations at interior points are necessary to which the three-point fixes at the buoys can be observed. The principal triangulation scheme along the coast usually provides stations on the tops of hills and the prominent interior features which can be used for this purpose.

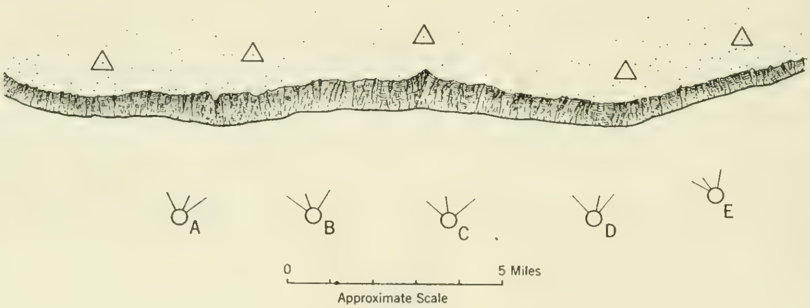


FIGURE 28.—Alongshore buoys located by three-point fixes at buoys.

The buoys are anchored in a line from $A$ to $E$ (fig. 28) paralleling the shore, at a sufficient distance offshore so that at least three shore stations are visible from each buoy station. Each should be located by a three-point sextant fix taken at the buoy, with a third angle to be used as a check if sufficient shore stations are visible. Each buoy station should be located by observations on shore stations exclusively; none of the observations should be on other buoy stations.

The positions of the buoy stations may be computed but such precision is rarely warranted. Sufficiently accurate positions may be obtained by plotting the three-point fixes with a metal protractor on an accurate projection on an aluminum-mounted sheet. When an aluminum sheet is not available, the fixes may be plotted on the smooth sheet, but this must be done immediately after the projection is made to avoid the possibility of distortion in the sheet. For immediate use in the field the three-point fixes may be plotted directly on the boat sheet. In such a scheme, corrections for the scope of the anchor cable are an overrefinement unless the stations are in deep water and long anchor cables are used. If scope corrections are applied to the plotted positions of the buoy stations they should be made as explained in **2511** and **943**.

It is interesting to note that the Hydrographic Service of Canada makes rather extensive use of this method for controlling inshore surveys along heavily wooded coastlines. Instead of using specially constructed buoys, however, they anchor small

evergreen trees buoyed and weighted to float upright; the tree branches and foliage make a perfect signal against the horizon.

This same method will sometimes serve to locate buoys much farther offshore, such as are treated in **2552**, especially when the atmosphere is exceptionally clear. Since the buoys are much farther offshore in this case, the sextant angles may have to be observed from a higher elevation on the ship to be able to observe on shore stations from such great distances. The three-point fixes at the buoy stations can sometimes be observed from the crow's nest at the time the buoy anchors are dropped, or at a later date when the ship is maneuvered to a position alongside each buoy.

### *2552. Sextant Locations Beyond the Visibility of Shore Signals*

In an occasional survey project the offshore zone of the survey may be best controlled from a single line of buoy stations approximately parallel with the shore. This usually occurs where the offshore depths are moderate and the hydrography must be controlled by sextant fixes, but tall shore signals cannot be seen at the required distance. For use as control in such an area a line of buoys may be anchored at a suitable distance beyond the limits of visibility of the shore stations and *cut in* from successive positions of the ship, drifting or at anchor, between the line of buoys and the shore. The scheme requires no special instrumental equipment and it may be used by any vessel equipped to handle buoys.

The buoys should not be anchored so far offshore that there will be difficulty observing them from ship positions within sight of shore signals. The buoys should be anchored with the shortest practicable anchor cables that will maintain them in their positions, in order to reduce to a minimum any errors of observations due to scope. The buoys should be approximately alined, the interval between adjacent buoys being slightly less than half the distance a buoy can normally be seen in the area at that season (see **2541**). The buoys $A$ to $G$ in figure 29 are not in alinement in order to show the small angles observed at the buoys.

The ship positions should be strong three-point fixes, as indicated in 1 to 10, figure 29, a check angle being observed at each if sufficient shore signals are visible.

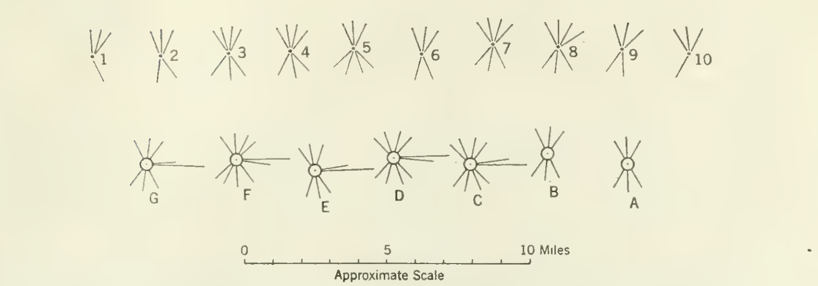


FIGURE 29.—Offshore buoys located by cuts from three-point fix positions nearer shore.

The ship positions should be selected so that at least three cuts intersecting at good angles are observed to each buoy. All buoys visible from each ship position should be *cut in*, in order that there may be as many cuts to each buoy as possible. All the angles at each ship position must be measured simultaneously and with the greatest accuracy, because any slight error in position is magnified proportionately in the cuts.

The strongest cuts are those normal to the shore but their intersections are often rather acute. This results in the positions of the buoys being better controlled in the alongshore direction than in a direction normal to the shore; that is, adjacent buoys are located with reference to one another more definitely in distance than in azimuth. To remedy this, sun azimuths should be measured between the buoys, or the small horizontal angle at each buoy between the next two buoys in line may be measured. These latter should be observed at the time the buoys are anchored. Referring to figure 29, after buoys *A* and *B* have been anchored and as buoy *C* is being anchored the small horizontal angle between buoys *B* and *A* is measured; in like manner the angle between buoys *B* and *C* is measured when buoy *D* is anchored, and so forth until the last buoy is anchored.

The geographic positions of the buoy stations are best determined by a graphic plot of the three-point fixes and cuts on an aluminum-mounted sheet. After the cuts to

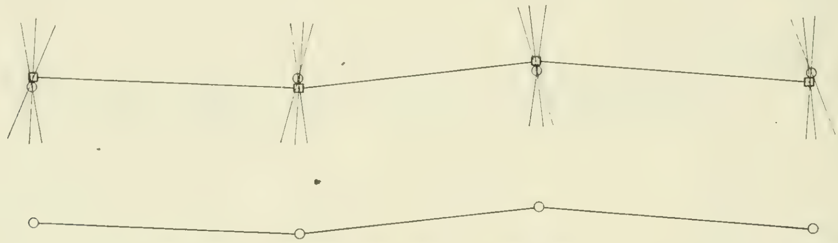

FIGURE 30.—Buoy positions strengthened by interbuoy observations. Lower line shows interbuoy azimuths. Upper line shows them adjusted to buoy cuts. (Preliminary positions marked ⊙; adjusted positions marked ⊡.)

the buoys have been plotted on the aluminum-mounted sheet the measured azimuths or the horizontal angles at the buoys are used to plot a succession of azimuths between buoys. These are plotted by means of a metal protractor on a piece of tracing paper, the preliminary positions of the buoys determined by the cuts being used as a base upon which to lay down the azimuths. This plot should begin at the buoy position having the best intersection of cuts. With the protractor center at this position and the small angle between the next two buoys in line set on the protractor, it is rotated until the two arms intersect the respective groups of cuts in the best possible manner. From these three tentative positions, the successive azimuth lines are plotted in both directions. After the plot is completed the entire tracing is adjusted to the plotted cuts and the most probable positions are accepted, always on the azimuth lines (see fig. 30).

### *2553. Line of Buoys Perpendicular to Shore*

A single line of buoys anchored along the axis of a narrow shoal extending offshore will often furnish adequate control for the closely spaced lines of soundings required for the development of the area. The positions of the buoys in such a line, established for this purpose or for any extension of control by buoys, may be determined by simultaneous angle observations, when such accuracy is warranted. This scheme requires no special distance-measuring apparatus and it may be executed by any ship that is

equipped to handle buoys, but at least four observing parties are required to measure simultaneous sextant angles.

Buoys are anchored in a line from *A* to *E*, as in figure 31, spaced so that they will be intervisible. The initial buoy *A* should be anchored with reference to the shore stations so that strong figures will be formed between it, the shore stations, and the inshore temporary ship positions (marked 1 and 5); and the successive buoys in line should be anchored so that the strongest practicable figures can be carried forward to maintain a maximum accuracy of position determinations. In general, buoys equally spaced in an approximate straight line will provide the strongest figures, and in no circumstance should the intervals between buoys differ greatly. Equilateral figures will doubtless give the strongest position determinations. While the buoys are being anchored, dead-reckoning data should be observed so that the approximate positions

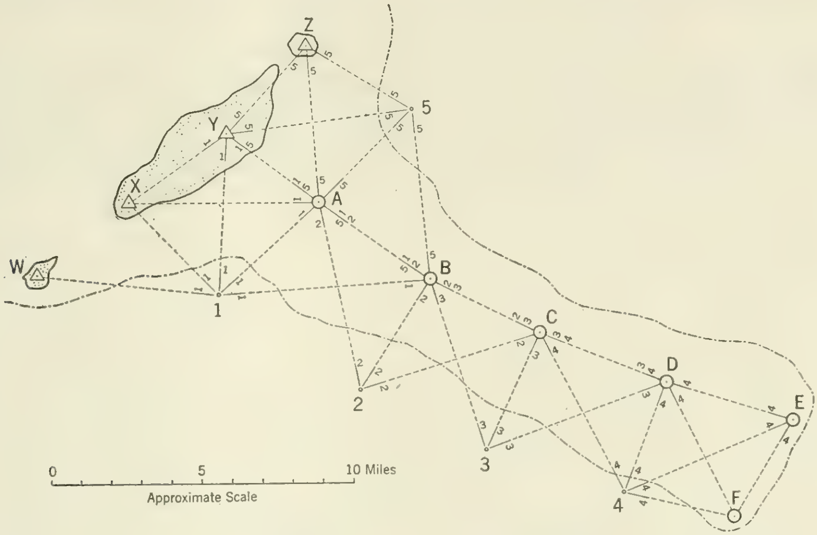


FIGURE 31.—Line of buoys located by simultaneous sextant angles.

of the buoys may be plotted and used to determine where the ship stations should be to form the strongest figures when the observations are made.

To obtain accurate positions of buoys by this method, the angles in each triangle in the scheme must be observed simultaneously and observations should be made on both sides of the line of buoys so that a check may be obtained on the positions determined.

The illustrated scheme shows the required observations and the method to extend the observations offshore, two methods of making the initial observations being shown. The first is shown with the ship at position 1 and illustrates the method of obtaining observations where three shore stations are available. The ship occupies position 1, a shore observer occupies station *Y* with a theodolite, and two launches with observers are sent to occupy buoys *A* and *B*. Simultaneous observations are made at all four stations by the visual method described in **2282**, or by any other means available. The directions marked 1 in figure 31 are obtained simultaneously at each station occupied and these observations furnish data so that the position of the ship at position 1 may be computed by the three-point problem, the position of buoy *A* computed with a check, and that of buoy *B* computed from the single triangle; these computations furnish the length and azimuth of the line *AB* which are then used to compute the triangles in carrying the computations ahead. After the observations at the first positions are completed, the ship moves ahead to position 2 and the shore observer at station *Y* is taken in a launch to occupy buoy *C*. Simultaneous observations are then taken as indicated by the directions marked 2, and in turn, observations through the scheme are made in this manner for each succeeding position of the ship, the launch observer at the inshore buoy always moving ahead to the next unoccupied buoy position.

If the shape of the shoal area requires it, an additional buoy *F* can be cut in without being occupied, the observations illustrated providing for a check on its position.

Where only two shore stations, as *Y* and *Z* in figure 31, are available from which to obtain the initial observations an observer must occupy each of the shore stations as illustrated for the ship at position 5. Observers are stationed at buoys *A* and *B* as before and with the ship at position 5, simultaneous observations are taken as indicated. Succeeding observations are obtained as described above until observations in the entire scheme are completed.

The positions should be computed on forms designed for the computation of geodetic positions and the observations on each side of the buoy line should be computed independently to obtain the distances between successive buoys, but the mean length between buoys should be used each time to compute the advance triangles, unless the positions are to be corrected for scope. Where the buoys are anchored in comparatively shoal water, the anchor cables will usually be so short that no appreciable error from this source will enter into the positions. If it is necessary to correct the positions for scope, two sets of positions should be computed from the observations on the two sides of the scheme. The corrections for scope should be made after the positions have been determined from each set of observations and the mean of each pair of corrected positions should be taken as the accepted position. (See **2511.**)

### *2554. Buoy Triangulation—Single Triangles*

A scheme of buoys arranged in triangles, may be used to furnish the control for hydrographic surveys in water areas from which shore signals are not visible. If such accuracy is warranted and there are triangulation stations on two land areas with a water area between, the buoy control may be located from the shore stations by a chain of well-shaped single triangles, as illustrated in figure 32. This method

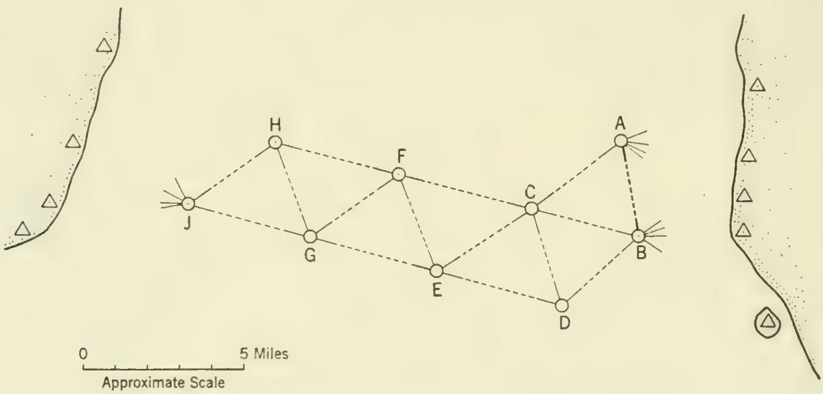


FIGURE 32.—Buoys located by sextant triangulation (single triangles).

and the method of buoy triangulation by quadrilaterals described in **2555** are especially useful when the survey vessel is not equipped with a taut-wire apparatus for measuring accurate traverses.

For greatest accuracy of positions in a scheme of this sort, the buoys should be arranged in a series of equilateral triangles, as in figure 32 between buoys *A* and *B* and buoy *J* whose positions may be strongly determined by observations on shore stations. The buoys must be anchored so that those in any one triangle are intervisible; hence the size of the triangles depends on the visibility at the locality. The scope of the anchor cables must be kept as short as possible and they should be moored, as explained in **2836** and **2851**, if there are strong erratic currents in the locality, or if a large-scale survey is planned. Mooring should not be necessary, however, where the direction and velocity of the current are approximately uniform throughout the entire area, because the buoys would maintain the same relative positions to one another.

Three-point sextant fixes are first observed at buoys *A* and *B* at one end of the scheme. A check angle on a fourth shore station should be measured at each of these fixes, if practicable. Current observations should be made in the vicinity at the time these fixes

are observed. The three angles in each successive triangle are next measured simultaneously (see 2282) by sextant observers stationed at the respective buoys in turn until a buoy is reached which may be located by a three-point fix on shore stations to tie the scheme again to shore control (see $J$ in fig. 32). The observed angles should be read to half minutes, and careful simultaneous observations should result in triangle closure errors no greater than 4 minutes per triangle.

Current observations are required at the tie-in buoys at ends of the scheme, but not at the intermediate buoys unless the current is dissimilar at the three buoys of a triangle.

The position computations for this type of scheme are made on the regular forms for the computation of geodetic positions. Buoys $A$ and $B$ are computed by the three-point problem on Form 655, the resulting data being used to solve the triangles on Form 25 and compute the positions on Form 27. The resulting positions are reduced to the anchor positions from the current data, and the length and azimuth of the line $AB$ are computed on Form 662, Inverse Position Computation. (See **2511.**) Positions are then computed for all buoys, including buoy $J$. Buoy $J$ is also computed from the three-point fix and the resulting position is reduced to the anchor position as for buoys $A$ and $B$.

The two positions of buoy $J$ will rarely agree within plottable limits and it will be necessary to adjust the positions in the scheme for the discrepancy. The accuracy of the method does not warrant a least-square adjustment, and a proportional adjustment through the scheme is sufficient. In the scheme illustrated seven triangles were used between the starting base $AB$ and buoy $J$. Accepting the positions of buoys $A$ and $B$ as correct, one-seventh of the discrepancy at buoy $J$ should be applied to buoy $C$, two-sevenths to buoy $D$, three-sevenths to buoy $E$, etc., and the three-point fix position of buoy $J$ should be accepted. These adjustments are made as corrections to the latitudes and longitudes of the original computed positions, based on the differences of latitude and longitude for the two positions of buoy $J$.

## *2555. Buoy Triangulation—Quadrilaterals*

Two lines of buoys anchored to form well-shaped quadrilaterals may be used instead of the scheme of single triangles described in **2554**. A scheme such as that shown in figure 33 will be found useful for the survey of a wide shoal area extending offshore, where a single line of buoys would not furnish adequate control.

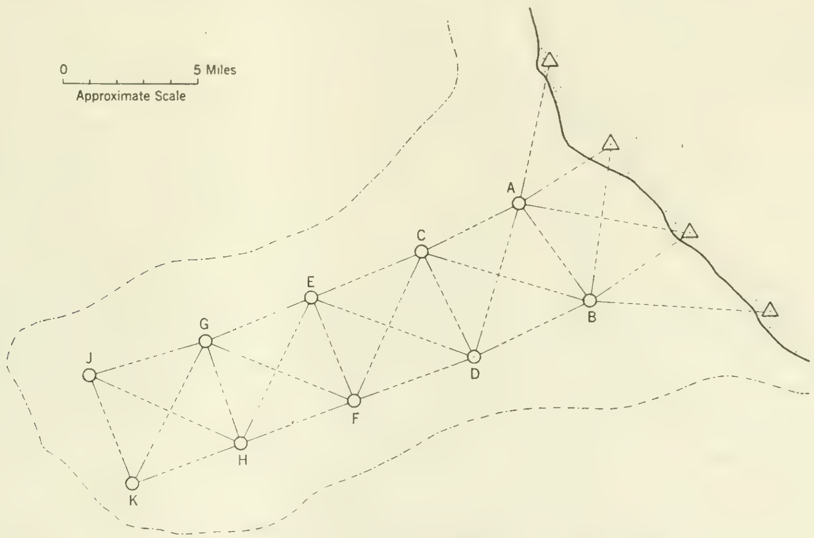


FIGURE 33.—Buoys located by sextant triangulation (quadrilaterals).

The necessary observations and position computations are similar to those described in 2554, where three-point sextant fixes are measured at the initial buoys $A$ and $B$ and current observations are obtained by which the observed positions can be reduced to the anchor positions. Simultaneous sextant angles are measured at the four buoys in each quadrilateral in succession, but two sets of observations are made in each so that the angles of each pair of triangles are measured independently. In the first set, angles are measured as follows: the observers at $A$ measure the angles $BAD$ and $DAC$ and the observers at $D$ measure the angles $CDA$ and $ADB$, while observers at $B$ and $C$ measure only the sum angles $DBA$ and $ACD$ respectively. Following this the angle measurements are repeated, but this time the observers at $A$ and $D$ measure only the sum angles and the observers at $B$ and $C$ measure the two separate angles at each buoy station. In like manner, simultaneous angles are measured in each quadrilateral of the scheme.

The two sets of independent observations, when obtained as described above, will furnish data permitting two independent sets of position computations through the scheme, each starting from the base $AB$. One set of computations is made through the diagonals $AD$, $CF$, $EH$, and $GK$ and the other through the diagonals $BC$, $DE$, $FG$, and $HJ$. The resulting positions will differ slightly and their means should be used to plot the positions on the smooth sheet.

## 256. Buoy-Control Schemes for Location by Taut-Wire Traverse

### *2561. Line of Traverse Buoys Parallel to the Coast*

Buoys anchored in a line approximately parallel with the general direction of the coastline can often be used advantageously to supplement the shore control in areas where the latter alone does not provide strong three-point fixes. This type of scheme provides economic offshore control between two coastal localities at which the end stations of a line of buoys may be located by sextant fixes to prominent shore objects, the hydrography in the intermediate area being controlled by buoy stations. The scheme may also be used to advantage along a broken coastline where it is necessary to establish control for inshore hydrography.

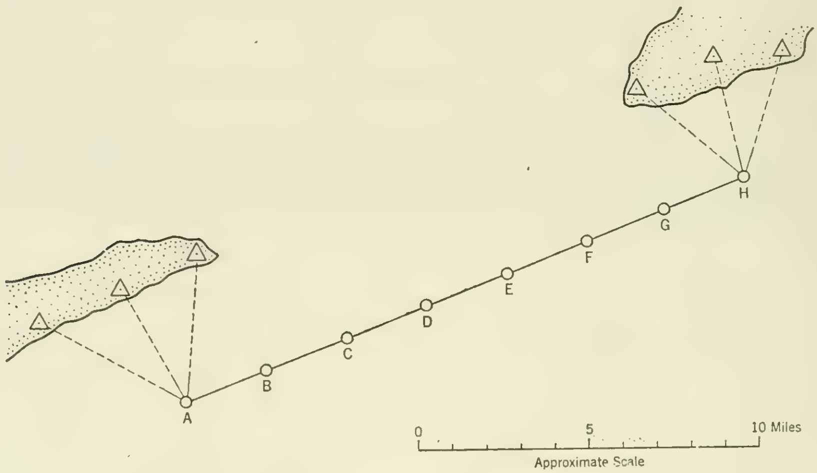


Figure 34.—Line of buoys parallel to the coast.

The scheme consists of a number of buoys anchored in a line between *A* and *H* (fig. 34) where strong position determinations may be made by sextant fixes. A uniform accuracy of the positions of all buoys in a scheme of this character is obtained by observing sun azimuths between adjacent buoys, measuring the distances between buoys with taut wire, and computing and adjusting the scheme as a traverse. The position of buoy *A* is computed from the sextant angles by the three-point problem and reduced to the position of the anchor. (See **2512.**) This position is used to compute the succeeding positions through the traverse, using the observed sun azimuths and measured taut-wire distances, to arrive at a traverse position of buoy *H*. The three-point sextant fix at buoy *H* is also computed by the three-point problem and reduced to the position of the anchor, which is held fixed. The difference between the latter and the traverse position of buoy *H* is the traverse error. The position of each intermediate station in the traverse is corrected by a proportional amount of this error according to its distance from the origin of the traverse at buoy *A*. (See **2554.**)

In some such schemes it may be possible to measure at each buoy one large sextant angle whose locus is approximately parallel to the line of buoys. Where this is possible the azimuth of the line can be controlled much better by the angles than by sun azimuths. In such cases the positions should be determined from a graphic plot on an aluminum-mounted sheet. The locus of the angle at each buoy station is plotted on the sheet (see **7625**) and the distances between successive stations are plotted on these loci, from the fixed position at one end of the line to the fixed position at the other end, the adjustments for closure being made graphically. The three-point fixes and the loci are plotted with a metal protractor.

In such a scheme, weak three-point fixes of doubtful accuracy should not be used for locating intermediate buoys nor used to adjust the traverse in sections, because larger errors are probable than should result from an adjustment between the two end stations where reliable positions are obtained.

### *2562. Traverse for Three-Point Fix Control*

In an area where shoal depths extend a considerable distance offshore and the hydrographic survey must be controlled by sextant fixes for a close development, a system of closely spaced lines of buoys may be required. Control of this type has practically replaced the tall hydrographic shore signals which were formerly used as control for such surveys (see **2721**). Buoys are now anchored comparatively close to the coastline or at positions where strong sextant fixes are obtainable, and large areas are controlled entirely by systems of lines of buoys tied to these fixed positions. The present trend is toward a wider spacing between lines of buoys in areas where R.A.R. methods operate efficiently, the hydrography in the mid-areas where sextant fixes cannot be obtained being controlled from sono-radio buoys located at strategic places in the system.

A typical scheme is shown in figure 35. Buoys are anchored in a line from *A* to *B* normal to the general trend of the coastline until the desired distance offshore is reached, then the direction of the line is changed to parallel the coastline from *B* to *H*, where the direction is again changed to normal to the coastline to a shore connection at buoy *I*. If the sounding lines are to be run normal to the coastline, the direction of the intermediate lines of buoys should also be normal to the coastline, as shown in the sketch, but if the sounding lines are to be run parallel to the coastline, the intermediate lines of buoys should preferably parallel the line between buoys *B* and *H*.

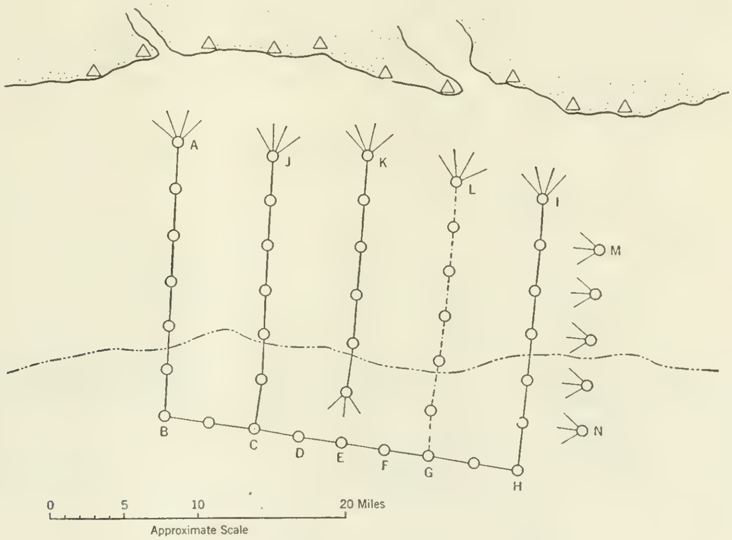


FIGURE 35.—Buoy control for three-point fixes.

The most accurate positions are obtained if all of the distances between adjacent buoys in lines are measured with taut wire However, this is not necessary, for the intermediate lines may be located as shown between buoys *E* and *K*, in which case the total distance to be measured by taut wire would be 8 percent less in the scheme illustrated. The distances between buoys in the intermediate lines may be measured by log, as illustrated in the line between buoys *G* and *L*, in which case 48 percent of the taut wire would be saved. Distances measured in both directions by two well-rated taffrail logs or a submerged log are considered sufficiently accurate for buoy control, provided both ends of the line are accurately located and a proportional adjustment of the closing error is made. An additional line of buoys, as shown from *M* to *N*, may be located by sextant fixes from the stations in a well-located line. The space between lines must be less, of course, but a second line of buoys should never be located by sextant angles from the first line so located, because this cannot be done with sufficient accuracy.

In a scheme of this type the lines of buoys from *A* to *B*, *B* to *H*, and *H* to *I* are usually computed and adjusted as a loop traverse (see **944**) and each intermediate line is then computed from the traverse position of the buoy in the loop to the inshore buoy whose position is fixed by sextant observations on shore stations. If taut-wire distances and sun azimuths are measured between all adjacent buoys in line, the computations and adjustments may be made between each successive shore connection. The loop *ABCJ* would be computed first and adjusted, and with the adjusted position of buoy *C* held fixed, the loop *CEK* would be computed, followed in like manner in each succeeding loop. This procedure is advisable when the final computations and adjusted positions are needed as the survey progresses along the coast.

### 2563. Traverse With Added Shore Connections

Where buoy stations are established for inshore hydrographic control it is frequently possible and advisable to obtain additional shore connections where the configuration of the coastline permits. Occasional shore connections increase the accuracy of positions in a buoy traverse and should be made when they require little additional time.

In the scheme illustrated in figure 36, established for the control of hydrography beyond the visibility of shore signals, it is possible, or necessary, to establish additional buoys in two lines extending inshore from buoy *C* and at each inshore buoy it is possible to obtain a strong three-point fix to shore stations. The same taut-wire sun-azimuth measurements are required in this type of scheme, but he computations differ in that a mean position of buoy *C* is determined to which all the lines are adjusted.


Figure 36.—Buoys located by traverse with additional shore connections.

Each buoy line, from *A* to *C*, *F* to *C*, *G* to *C*, and *E* to *C*, is computed from the fixed position of the inshore buoy in the respective line, resulting in four independent positions of buoy *C*. A mean position of buoy *C* is found by weighting the four positions inversely according to the lengths of the respective lines. The positions in each traverse line are then adjusted proportionally to the fixed positions of the inshore buoys and the mean position of buoy *C*.

Also illustrated in figure 36 is a short line of buoys extending from buoy *B* to buoy *H*. This is called a ***spur*** line and all of the positions in such a line are located with the same accurate observations, but it is adjusted by applying the correction to buoy *B* to all buoy positions in the spur line, without additional adjustment.

### 2564. Traverse to Establish Datum

A carefully planned buoy traverse may be used to extend a geodetic datum to an isolated island, where it is impossible or difficult to do so by triangulation. If the distances are measured with an accurately calibrated taut-wire apparatus and the sun azimuths are observed carefully, the datum provided by the traverse will be sufficiently accurate for charting purposes.

The lines of buoys should be planned to extend from the adjacent land areas to the isolated island by the shortest practicable distances, and from points where strong determinations may be obtained from established triangulation stations. (See fig. 37.) Each buoy traverse should be practically straight and the two should be approximately at right angles to each other. The interval between buoys should be a maximum in order to reduce azimuth errors to a minimum. The sun azimuths must be observed with unusual care and the necessary data must be obtained for correcting the azimuths to the anchor positions of the buoys (see **9432**). Each buoy traverse must be measured

in one continuous operation to eliminate any error that might result if it were measured in sections. The positions of the end buoys at $A$ and $C$ (fig. 37) should be determined from theodolite angles measured simultaneously at three or more shore stations.


FIGURE 37.—Taut-wire sun-azimuth traverse to extend geodetic datum.

The traverse, starting at buoy $A$, running to buoy $B$, and continuing to a shore connection at buoy $C$ is computed as an ordinary traverse but with extra care and refinement to obtain greater accuracy. A point connection is made at buoy $B$ by simultaneous observations from three shore stations on the isolated island which, combined with a base and azimuth measurement, will furnish the required data from which the geographic positions of the stations on the island may be computed. The accuracy of such a scheme, although not as high as where a single straight traverse is used, will be indicated by the traverse closure.

A more accurate value of the distance will be obtained if the buoy traverse can be arranged to extend in one straight line from the initial station to the tie-in station, passing the isolated island at a satisfactory distance so that a point connection may be made. This, however, will seldom be possible or economic in practice.

A traverse for this purpose should never consist solely of measurements in two directions along the same line of buoys (from $A$ to $B$ and from $B$ to $A$) and computed and adjusted as a closed traverse, for an apparently excellent agreement in distance might be obtained, even though the taut-wire calibration were considerably in error.

## 257. Buoy-Control Schemes for Location by Other Methods

### *2571. Astronomic Location in an Isolated System*

To survey adequately an isolated offshore shoal area of critical depths, buoy stations are required for control of a system of closely spaced sounding lines. If the area is so far from shore stations that a taut-wire traverse connection is impracticable, the geographic position of the survey is generally based on independent sextant astrono-

mic observations. This gives sufficient accuracy for charting the survey, but the principal object is to coordinate the survey as a whole.


FIGURE 38.—Buoy control for an isolated offshore shoal.

The buoy station to be located by astronomic observations should be anchored near the center of the area or in shoal water near the critical depths, as at $A$ in figure 38. Observations to determine the position of this buoy should be made as described in **2535**. From this buoy as an origin, buoys are anchored in lines approximately along the axis of the shoal so as to furnish control in the most efficient manner. Taut-wire sun-azimuth measurements are made along these lines of buoys, which are computed as unadjusted traverses. (See **2525**.) It is wasted effort to locate the end stations by sextant astronomic observations for the purpose of adjusting the traverse between them, because the traverse measurements are much more accurate than the astronomic observations.

### *2572. Stations for R.A.R. Control*

Along certain types of coasts it is practicable to establish R.A.R. stations far enough offshore so that surveys can be controlled by this method to the desired offshore limits. Along the Pacific Coast and the coast of Alaska the positions of sono-radio buoys may be determined on clear days at a considerable distance offshore by three-point fixes on high mountain peaks whose positions are known.

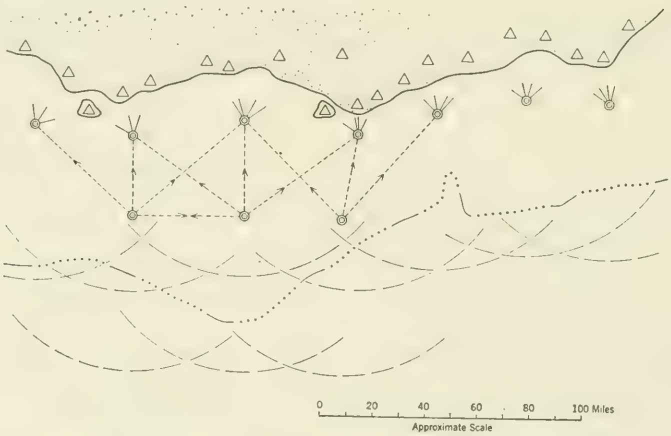


FIGURE 39.—R.A.R. stations located by three-point fixes and acoustic distances.

Frequently only one line of R.A.R. stations is necessary to furnish the control for the desired offshore area, but stations must be so distributed that returns from at least three R.A.R. stations may be expected throughout the area to be surveyed.

(Fig. 39.) The selection of sites for stations will depend principally on the effectiveness of R.A.R. in the particular locality.

The offshore limit of the area to be surveyed is frequently beyond the limit of reliable acoustic distances and R.A.R. stations must be established farther offshore to furnish reliable control. Shore stations may not be visible from these offshore positions to provide three-point fix locations of the R.A.R. stations, but they may be located by acoustic distances by the method described in **2533**.

### *2573. Traverse for R.A.R. Control*

Where the hydrographic survey of an offshore shoal area is to be controlled by R.A.R. methods, but the coast is so low that shore signals are visible for only a short distance offshore, a buoy traverse may be used to extend the control to the offshore area, and from buoy positions so determined, R.A.R. stations may be located farther offshore by acoustic distances. This method is frequently used on the Atlantic and Gulf Coasts where inshore areas have been previously surveyed and it is desirable to extend control to offshore areas in a rapid and economic manner.

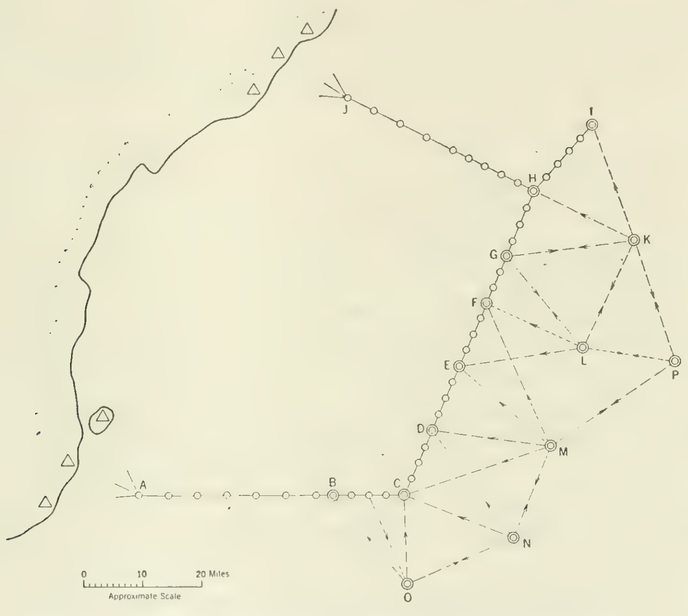


FIGURE 40.—Sono-radio buoys located by traverse and acoustic distances.

The lines of buoy stations between *A*, *C*, *H*, and *J* in figure 40 are located and observed so that they may be computed and adjusted as a closed traverse between fixed positions at *A* and *J* (see **944**). The distance between adjacent buoys in the area previously surveyed may be a maximum, but the buoys in the area to be surveyed should be spaced to provide for three-point fixes if it is desired to control the area adjacent to the buoy lines by this method. Frequently, in an area of this character, the buoys in the traverse may be spaced at a maximum distance throughout and the entire area controlled by R.A.R. methods.

Sono-radio buoys are located at intervals in the traverse line, as indicated by the double concentric circle symbols, which are lettered from *B* to *I* in the figure. The required distance between adjacent sono-radio buoys depends on the efficiency of

the R.A.R. method. Sono-radio buoys placed 12 or 15 miles apart will usually furnish adequate control in an average area, but they must be spaced at closer intervals where the R.A.R. method is limited to short acoustic distances.

Other sono-radio buoys are anchored offshore from the traverse line and these are located by acoustic distances from the sono-radio buoys in the traverse (see **2533**). It is important to place these stations close enough to the traverse line to be well within the limits of reliable returns, and each should be anchored at unequal distances from the traverse stations from which distances are to be measured, to prevent the returns from two stations being recorded simultaneously on the chronograph tape and being unidentifiable (see **6814**).

The time intervals are usually measured with the source of sound located at the stations whose positions are to be determined, but where the buoys to be located are sono-radio buoys, the source of sound may be located at any ordinary buoy station in the traverse. It is frequently possible and desirable to measure the time intervals in both directions; first when the offshore stations are anchored, and subsequently just before the sono-radio buoys in the traverse line are weighed, or at any time the vessel is in the vicinity of a station at one end of a line whose length is to be determined. It is advisable to measure the time intervals between two stations as often as it is convenient to do so without consuming too much time, for each additional measurement increases the strength of the position determination, if reliable data are obtained (see **2533**).

In an extensive area it is frequently necessary to establish R.A.R. stations still farther offshore, and where the R.A.R. method operates efficiently the positions of these may be located by acoustic distances from the stations first so located. If the acoustic distances are not sufficiently reliable for this, the positions may be materially strengthened by measuring, with taut wire, the offshore distance from a station in the traverse line. In figure 40, the distance from buoy *F*, in the traverse line, to buoy *L* and the distance from buoy *L* to buoy *P*, the offshore sono-radio buoy, would be measured by taut wire. These measurements will serve to strengthen the entire scheme for they will provide comparatively accurate offshore distances of buoys *L* and *P*. In an area controlled by R.A.R. methods a dependable offshore distance has an additional value, for it may be used for an experimental determination of the velocity of sound (see **6352**).

The adjusted positions of the stations in the traverse are determined by the regular computations for a traverse (see **2525** and **2561**). The positions of the stations located by acoustic distances are determined from a graphic plot on an aluminum-mounted sheet of sufficient size to include the required traverse stations on a scale slightly larger than the smooth sheet. If aluminum-mounted topographic sheets are used, two or more may be required, or a grained aluminum sheet of sufficient size may be used (see **7131**). The computed positions of only the required traverse stations are plotted by *dms.* and *dps.* and the acoustic distances to each station are plotted with a beam compass, the required positions being determined as explained in **2533**. The taut-wire distances are also plotted with a beam compass but they are accepted as correct, and the positions of the respective stations must be accepted on the arcs representing taut-wire distances.

### *2574. Subaqueous Quadrilaterals*

In offshore areas where the general depths permit anchoring buoys but are not so shoal as to require closely spaced lines, a system of control by R.A.R. methods may be located entirely by subaqueous sound ranging. The method is limited to localities

where subaqueous distances may be reliably measured, but its accuracy depends primarily on the accuracy with which the velocity of sound in sea water may be determined (see **635**). In an area of moderate and uniform depths, where the velocity may be determined within 2 meters per second, positions of the control stations sufficiently accurate for the survey of an offshore area may be obtained by this method.

The scheme, as illustrated in figure 41, may be compared to a system of triangulation quadrilaterals in which the lengths of all sides and diagonals are measured, instead of the angles. Instead of being planned for intervisibility between stations, the scheme must be planned so that the distances between stations in the same quadrilateral are considerably less than the maximum expected to be reliably measured by subaqueous sound ranging.

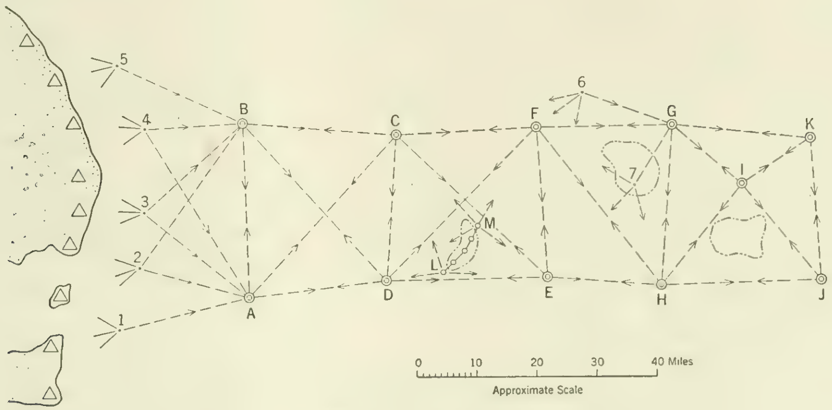


FIGURE 41.—Sono-radio buoys located by acoustic distances.

Sono-radio buoys are anchored at stations $A$ and $B$ at a suitable distance offshore and located by subaqueous distances from successive ship positions 1 to 5 determined by three-point sextant fixes on shore stations (see **2534**). This establishes a base $AB$ whose length is further checked by subaqueous distances measured at both ends of the line (see **2533**), and from which the scheme is extended into the offshore area. Additional sono-radio buoys are anchored to form quadrilaterals with sides of slightly unequal lengths, so that, when measured, the bomb returns will not be recorded simultaneously on the chronograph tape (see **6814**). It is desirable that the time intervals be measured over each line in both directions in order to obtain a double determination of the distance. This will generally be possible, but it will require at least six sono-radio buoys, so that one may be placed at each station of two adjacent quadrilaterals. After the required time intervals have been measured in adjoining quadrilaterals, the two inshore sono-radio buoys may be replaced by ordinary buoys and anchored at the next offshore stations. If stable velocity conditions exist, which are likely to worsen later, this procedure should be continued until all of the stations which will be required in the area have been determined.

It is usually neither necessary nor practicable to connect both ends of a scheme of this type to shore stations for it generally extends into deep water where less accuracy may be tolerated. If it is feasible to do so, however, the scheme should be extended to another shore connection, in which case a proportional adjustment of the closing error should be made. It might be possible to extend the scheme in the same general direction to a land area with control stations computed on the same datum; or it might

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be practicable to connect the offshore end of the scheme with another similar scheme approximately parallel to it extending offshore from the adjacent land area.

At times when, and in areas where, the R.A.R. method of control operates efficiently, the size of the quadrilaterals may be large, but they must be correspondingly reduced in an area in which the method is not so efficient. Banks and irregular depths in the inshore areas frequently interfere with the measurement of subaqueous distances and it is necessary to start the scheme from a closed taut-wire traverse. The traverse need extend offshore only far enough to establish reliable positions beyond the area of irregular depths, the remaining stations in the scheme being located from the positions of sono-radio buoys in the traverse (see **2573**).

In a scheme of this character it is likely that the lengths of certain lines cannot be measured by subaqueous methods because of shoals or intervening irregular depths within the area. Such a line may be measured by taut wire or by one of the two methods illustrated in figure 41. The diagonal between buoys *E* and *G* could not be measured, but the position of buoy *G*, determined by measurements of the distances from *F* to *G* and *H* to *G*, may be verified by a distance to buoy *G* obtained from position 6 which in turn has been located by acoustic distances from *C*, *F*, and *E*. A position for this purpose must be carefully selected so that it may be accurately determined and the measurements must be made with extra care.

A position on the shoal, as shown at position 7, should be used with extreme caution. A return will probably be received from buoy *G* but, because of the intervening shoal, the path of the sound wave is uncertain and consequently there will be uncertainty in the computed distance.

In the adjoining quadrilateral neither of the diagonals could be measured directly because of an intervening shoal, but from the supplemental buoy *I* it was possible to measure distances to the four buoys at the corners of the quadrilateral. With these and the sides of the quadrilateral measured, an adjusted graphic plot will determine the coordinated positions.

Positions in a scheme of this type are determined by a graphic plot on one or more aluminum-mounted sheets as explained in **2573**.

Offshore areas are likely to contain shoals which require thorough development and lines of soundings more closely spaced than is practicable by R.A.R. On or near such an area a line of buoys may be anchored to furnish control for three-point fixes. The buoys should be established in a line parallel to the axis of the shoal. The end buoys, *L* and *M* in figure 41, are located by subaqueous distances from the adjacent sono-radio buoys. The intermediate buoys in the line are located by sun azimuths and taut-wire distances and their positions are computed as an adjusted traverse between the end buoys (see **2561**). The positions of the survey buoys, when located in this manner, are referenced with sufficient accuracy to the positions of the sono-radio buoys so that the positions in the entire scheme are adequately coordinated.

## 258. Statistics of Buoy-Controlled Surveys

Hydrographic surveys in areas where buoy stations are required for the control, either for sextant fixes or R.A.R. methods, are different from hydrographic surveys controlled from shore stations. They require a different planning and a different technique of execution. The tabulation is intended as a guide to the requirements and possible results to be expected under different conditions in different areas. The statistics are from actual typical projects controlled by the different types of buoy schemes described in **255**, **256**, and **257**. General information regarding each project is given.

TABLE 5.—*Statistics of typical hydrographic survey projects using buoy control*

| | (1) Gulf of Mexico, 1938 | (2) Gulf of Mexico, 1939 | (3) Pacific Coast, 1933 | (4) Atlantic Coast, 1939 | (5) Gulf of Maine, 1940 |
|---|---|---|---|---|---|
| Sounding lines (statute miles) | 15, 260 | 17, 621 | 13, 407 | 10, 496 | 15, 334 |
| Fixed positions (number) | 20, 310 | 13, 015 | 4, 248 | 7, 503 | 10, 992 |
| Area (square statute miles) | 10, 331 | 36, 758 | 15, 874 | 8, 562 | 8, 901 |
| Control buoy stations, including sono-radio (number) | 252 | 138 | ---- | 84 | 53 |
| R.A.R. stations do | ---- | 32 | 7 | 24 | 22 |
| Taut-wire traverse (statute miles) | 819 | 278 | ---- | 271 | 96 |
| Serial temperature stations (number) | 119 | 44 | 50 | 135 | 138 |
| Trinitrotoluene (TNT) (pounds) | ---- | 2, 263 | (1) | 3, 511 | 5, 200 |
| Fuse (feet) | ---- | (1) | (1) | 4, 170 | 5, 300 |
| Bombs, various sizes (number) | ---- | 1, 607 | 2, 083 | 5, 506 | 8, 904 |
| Total working days do | 154 | 136 | 298 | 101 | 107 |
| Days to establish control do | 24 | 15 | 28 | 18 | 18 |
| Mileage of survey vessel (nautical miles) | 19, 372 | 24, 400 | 18, 906 | 16, 481 | 20, 564 |

[1] Data not available.

*Column 1.*—Statistics of a project of offshore surveys off the Texas Coast from April 18 to November 11, 1938. The surveys were plotted on six 1:40,000 scale sheets and two 1:80,000 scale sheets and were controlled almost entirely by three-point sextant fixes and dead reckoning from buoys established in a scheme similar to that described in 2562.

*Column 2.*—A season's project of offshore surveys off the Texas and Louisiana Coasts from April 25 to November 13, 1939. The season's hydrography was plotted on three 1:20,000 scale sheets, four 1:40,000 scale sheets, two 1:80,000 scale sheets, and one 1:240,000 scale sheet. The surveys were controlled by three-point sextant fixes and R.A.R. methods from a combination of the schemes described in 2562 and 2573.

*Column 3.*—The surveys of this project off the coast of Southern California were plotted on three 1:20,000 scale sheets, six 1:40,000 scale sheets, and three 1:120,000 scale sheets during the period between December 5, 1932, and January 30, 1934. The control was by R.A.R. methods using seven shore stations, supplemented by three-point fixes where shore signals were visible. The R.A.R. stations were established along the shore in a manner similar to that described in 2572.

*Column 4.*—The statistics in this column are from an offshore survey of Nantucket Shoals and the adjacent continental slope plotted on one 1:60,000 scale sheet and two 1:120,000 scale sheets. The surveys, between May 2 and September 25, 1939, were controlled exclusively by R.A.R. methods, the buoys being established in a scheme similar to that described in 2573.

*Column 5.*—An offshore project in the Gulf of Maine controlled entirely by R.A.R. methods and plotted on two 1:120,000 scale sheets. The surveys were started on April 12, 1940, and the season's work ended on September 12. The control was established by the method described in 2574, from stations located by taut-wire traverse just beyond the inshore shoals.

## 26. R.A.R. STATIONS

In addition to sono-radio buoys (see **284** and sections **64** and **65**), R.A.R. shore stations and ship stations may be used to receive subaqueous sound and transmit the instant of its arrival to the survey ship. Sono-radio buoy stations are in general use for R.A.R. control, but it may be that shore stations can be advantageously substituted for them in some areas.

### 261. R.A.R. SHORE STATIONS

During the early use of R.A.R., shore stations were used exclusively for receiving stations, but the completely automatic sono-radio buoy is now used exclusively on the Atlantic and Gulf Coasts and probably has replaced the shore station almost entirely. On the Pacific Coast and in Alaska, where deep water approaches the shore and strong currents make the use of sono-radio buoys difficult, shore stations may still be useful. The general arrangement of an R.A.R. shore station is shown in figure 42.

#### *2611. Selection of Shore Station Sites*

R.A.R. shore stations for hydrographic control should be established along a coast as outlined in **2572**. On the open coast ideal sites are rarely available where needed and often a site lacking one or more of the requirements must be accepted. The re-

quirements for a shore station site, in the approximate order of their importance, are as follows:

(*a*) The shore station site must be within a reasonable distance of the hydrophone (see **2612**) and usually convenient thereto. If practicable the hydrophone site should be visible from it so that the station operator can notify the ship personnel when small boats cause interference.

(*b*) It must be accessible by water or overland transportation.

(*c*) Fresh water should be available at the station and supplies should be obtainable in the vicinity for the station personnel.

(*d*) It is desirable to house the station and personnel in existing facilities on shore, otherwise a house must be built or tents erected for this purpose.

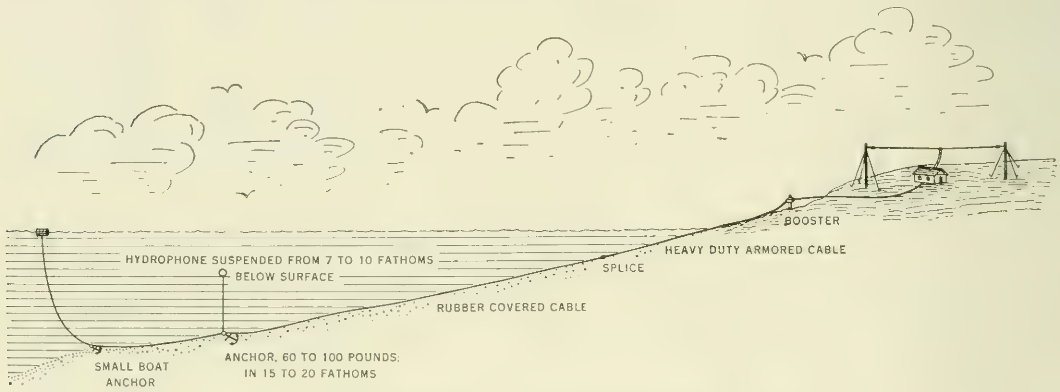


FIGURE 42.—R.A.R. shore station (general arrangement).

### *2612. Hydrophone*

The hydrophone unit used in the shore station equipment must be in a light container of sufficient size and displacement to furnish buoyancy. It should be provided with a valve and be strong and tight enough to contain air under pressure (see **6563**, Vincent Hydrophone). A large container, 24 inches in diameter, made of ¼-inch boiler plate, has been used successfully with about 35 pounds of air pressure.

The hydrophone is anchored in depths of 15 to 20 fathoms (see fig. 42) so that it floats submerged 7 to 10 fathoms below the surface of the water. An anchor of scrap iron, weighing from 60 to 100 pounds, is attached 5 to 13 fathoms from the end of the cable to which the hydrophone is attached. This holds the unit at the desired depth below the surface. One end of a length of ⅜-inch wire rope, about as long as the water is deep, is attached to the hydrophone anchor and stretched along the bottom, a small boat anchor being attached to the other end. A small marker buoy is secured to the boat anchor for use in recovering the hydrophone. The hydrophone and the buoy must be separated far enough so that there is no likelihood of the hydrophone becoming fouled. All connections and shackles must be made tight so that the motion of the water cannot possibly make them clank or rattle in the slightest, to cause unwanted noises in the hydrophone.

*a. Hydrophone site.*—The selection of the hydrophone site is the most important factor in the establishment of a shore station. The hydrophone should be located at the edge of a slope into deep offshore water. Shoals and submarine valleys between the hydrophone and the area being surveyed are apt to interfere seriously with the transmission of sound. The hydrophone should be located as close as practicable to the beach so that only a short length of cable is necessary.

The conditions between the hydrophone and the shore will affect cable-laying operations to an important degree. A beach and a sea bottom of smooth sand, free from rocks, are most desirable; rocky kelp-covered ledges are most unfavorable. Landing of cable through the surf is difficult and in general can be done only when there is little swell. In some cases it may be possible to avoid delay in establishing a shore station by selecting a hydrophone site near a cove or small bay that affords a protected landing.

### *2613. Cable*

Two types of cable are used in installing shore-station hydrophones. On rocky bottom, in areas of kelp, and through the surf, a heavy-duty cable is required. The specifications for this cable are as follows:

Cable, armored, ⅛-inch center of 19-wire tinned aircraft strand, insulated with 5⁄32-inch ignition cable compound of at least 33 percent pure rubber, covered with double braid and armored with 14 wires of No. 14, B.W.G. double-galvanized wire.

On smooth bottom in an area where it will not be chafed, a light-duty cable of the following specifications is used:

Cable, ⅛-inch center of 19-wire tinned aircraft strand, insulated with 5⁄32-inch ignition cable compound of at least 33 percent pure rubber.

This cable is very strong but it is so light that it will not bury itself in sand. It may be used between the hydrophone and the outer line of breakers. Where the bottom is sandy and the sea smooth with rarely any breakers, it has been used for the entire installation from hydrophone to shore with fairly good results. As single-conductor cable is used in most shore-station installations, a ground must be provided at both ends. At the offshore end, the metal case of the hydrophone in contact with the water has been found satisfactory; and at the shore end, a connection to a metal rod driven in the ground will usually suffice.

Hydrophone cable should be tested for *leaks* or *shorts* before use. An approved method of testing is to submerge the entire reel of cable in sea water, except one end used for the measurements. The other end of the cable, if it is submerged, must be made watertight. The resistance between the conductor cable and sea water may be measured with a 150-volt megger. For a 3,000-foot length of cable, the leakage resistance should be not less than 10,000 ohms.

To locate a leak in a cable, it may be run through sea water so that only about 10 feet is submerged at a time, the leakage resistance being measured continuously meanwhile. A sudden deflection of the pointer of the megger will indicate that the cable is leaking where it enters the water.

All splices in a hydrophone cable must be soldered, mainly for strength, and each splice should be covered with several layers of Pará-rubber tape which, in turn, is covered with several layers of friction tape.

A magnetic unit of low impedance, in which other favorable characteristics have not been sacrificed, should be used, if obtainable, because it is less affected by leakage than other types are.

*a. Laying cable.*—If the selected hydrophone site is in an inadequately surveyed area, a hasty survey of the vicinity should be made on a special boat sheet. Several short sounding lines in the vicinity of the proposed hydrophone anchorage and several sounding lines between there and the beach should suffice. The best spot for anchoring the hydrophone can then be selected, the exact depth will be known, and the approximate lengths of different types of cable required may be determined.

The survey ship, or a launch, should anchor at the approximate position of the hydrophone. The tested cable, wound on a reel with the heavy-duty cable on top, is placed in a whaleboat or motor sailer so that it may be readily unreeled. The small boat with the cable proceeds to the beach, or to a safe anchorage just offshore from the breakers from where the cable is hauled ashore by a heaving line. Heavy surf or a wide stretch of breakers may necessitate the use of a Lyle gun to shoot the line ashore, or the laying may have to be postponed until sea conditions are more favorable. After the end of the cable has been pulled ashore and secured, the small boat heads toward the anchored ship, paying out the cable. When the ship is reached, the end of the cable is passed aboard where it is spliced to the hydrophone, and the anchoring assembly as described in **2612** is attached. The hydrophone anchor is first lowered by a trip line, followed by the buoy anchor which is anchored as far from the hydrophone anchor as the wire rope connecting them will permit.

### *2614. Electric Equipment*

The electric circuits of the amplifier and transmitter may be identical with the sono-radio buoy circuits (see section **65**), except that 6-volt transmitting tubes are used because they are more reliable and there is not the same need to conserve power. And a separate bomb-listening circuit may be incorporated in the amplifier. There are numerous advantages to be gained from the latter. Some of these are: the gain of the listening circuit may be controlled independently from the main amplifier, interaction between the listening circuit and the main amplifier is reduced, and spurious noises caused by the operation of the keying circuit and radio transmitter are eliminated from the listening circuit.

Another useful arrangement is to connect the radio transmitter to the amplifier so that the circuit may be kept open at all times except while held closed manually, as by a push button in the circuit. The push button can be pressed a few seconds before the expected arrival of a bomb signal, the time being judged from the approximate distance of the ship from the hydrophone. In this way the radio transmitter is kept inoperative until just before the arrival of the bomb signal, thus reducing the likelihood of its being operated by water noises.

Where the shore station is at some distance from the inshore end of the hydrophone cable, a two-stage amplifying booster is usually inserted about midway between the hydrophone and the station equipment. The booster is contained in a waterproof box, located well inshore from the high-water line at a protected place. It may contain its own power supply or be supplied with power from the shore station. The inshore end of the hydrophone cable is connected to the booster, a land line extending from there to the shore station. The gain of the booster amplifier is fixed and any necessary change in gain is made at the shore station amplifier.

The electric equipment is battery operated, because an a-c power supply is rarely available where shore stations are needed. A portable gasoline-driven generator is needed for charging the batteries.

### *2615. Antenna*

The antenna may be erected between two trees from which the interfering branches have been removed. If trees are not available it is generally necessary to erect two well-guyed masts at a suitable distance apart. The axis of the antenna should be approximately at right angles to the area to be surveyed.

Where the supporting structures can be placed far enough apart, the length of the antenna should be one-half the wave length according to the formula:

$$\text{antenna length} = \frac{l}{2} = \frac{c}{2f}$$

where $l$ = wave length (in meters).
$c$ = velocity of radio waves (300,000,000 meters per second).
$f$ = frequency of radio waves to be transmitted (in cycles per second).

The antenna should be as high above the ground as the supporting structures will permit, but under no circumstances should this be less than 15 feet. The antenna should be insulated at each end by means of high quality strain insulators.

The radio set may be connected to the antenna by a transmission line composed of a single wire or several wires spaced by insulating spreaders. The connection may be made to either the end or center of the antenna.

#### *2616. Radio Frequencies*

The shore station radio transmitters operate on frequencies ranging from 1,700 kc. to 5,000 kc. For distances involved in R.A.R., frequencies with this range will give the most consistent results for day and night operations. The particular frequency within this range is selected by determining in advance which one of the available frequencies is most free, in the project area, from interference from other radio stations. Quartz crystals to fix the frequency of the transmitter should then be requested from the Washington Office. Shore stations should have on hand crystals for the 1,700, 2,000, and 4,000 kc. bands, so that the transmitter's frequency may be quickly changed if interference from other radio stations occurs on one frequency. The frequencies available to the Coast and Geodetic Survey for R.A.R. purposes are listed in **6441.**

### 262. Ship Stations

When R.A.R. control was first used on the Atlantic Coast it soon became apparent that shore stations could be used for only limited distances offshore, far less than was required for the extensive shoal areas common on that coast. Before the development of the sono-radio buoy, ship R.A.R. stations were employed to extend the control farther offshore.

The station ship was, in reality, a mobile shore station that could be anchored near a located marker buoy or at a position where it could be located by sextant fixes. The station circuits were identical with those used at shore stations, but the hydrophone was buoyed and trailed astern of the ship on a cable of sufficient length to remove it from ship noises. On offshore surveys the relation between the hydrophone and the marker buoy was measured at frequent intervals and transmitted to the survey ship so that the correct position of the hydrophone could be plotted on the boat sheet.

Ship stations have not been used in R.A.R. surveys since the first successful use of sono-radio buoys.

## 27. SIGNAL BUILDING

### 271. General Statement

Hydrographic surveying consists essentially in determining the depths of the water at consecutive known positions of the survey vessel. There are two principal methods used to determine positions. The first and older is by the measurement, with sextants on board the vessel, of angles between visible shore objects or buoys, whose geographic positions are known. The second and newer is by Radio Acoustic Ranging,

described in chapter 6, an indirect method which does not depend on the visibility of objects.

For the first method either a sufficient number of natural objects must exist or artificial objects must be constructed. It is with the construction of these latter, signals and buoys, that this section and section **28** deal. In the Coast and Geodetic Survey, the term *signal* is used loosely to indicate any sort of artificial object erected or established on the land for use in measuring sextant angles to locate the positions of survey launches and vessels engaged in sounding. A signal may be a white washed rock, a 100-foot tower, or a handkerchief-sized banner on a bush. The term is sometimes even used to indicate a natural object used for control. (See **2111.**) The term *buoy* is likewise used loosely to indicate any anchored floating object, with or without superstructure, used for control purposes.

It is obvious that hydrographic surveying is greatly facilitated when the objects at the control stations are conspicuous enough to be seen readily by the observers. For this reason, as well as for economy and durability, natural objects such as lone boulders, pinnacle rocks, waterfalls, lone trees, and distinctive marks on cliffs, and artificial objects such as tanks, lighthouses, spires, and building gables, should be used for control wherever available.

Signal structures erected at stations vary in type and size, depending on their location, purpose, and the materials available. Their size and elevation above high water depend on whether they are to be used for launch or ship hydrography and at what distance they need to be visible. Advantage should be taken of natural elevations of the ground upon which to erect signals, where they need to be seen at considerable distances.

Where a signal is to be used at a long distance, the target not only must be of considerable size but must be constructed and dressed so that it will stand out in contrast to the background and be as conspicuous as possible. In this respect white is best against a dark background and black is best against the skyline, provided the target is elevated sufficiently or constructed so as not to blend in with ground objects. When white targets are used, they should be constructed to reflect as much sunlight as possible. The principal advantage is to be gained from a white target only when the sun shines on it, and one which must be pointed away from the sun can be seen ordinarily only from comparatively short distances. But under certain conditions, a white target illuminated by the sun on its inshore side will stand out conspicuously against a nearby dark background of trees or cliff. A sloping target will reflect the most sunlight and consequently will be visible at the maximum distance. The slope should be from 45° to 60° and the signal should be constructed and dressed in accordance with the conditions encountered. A tripod structure dressed with white signal cloth to resemble a 9- by 9-foot tent of the centerpole type makes an excellent signal.

Where shore signals are needed to control offshore ship hydrography in areas where the coastline is low and flat, targets have to be placed on high structures to be visible from any appreciable distance offshore. To obtain better reflection from the sun, it is sometimes advisable to orient the signal and target at a slight angle to the shoreline, rather than have it face directly offshore. This angle should not exceed 15°. To construct the target at an angle to give it greater reflecting power, the target boards can be shimmed at the bottom to give the target a *Venetian-blind* effect, and can be slightly sprung around the tower to present a convex surface to seaward.

For the control of launch hydrography, it is seldom necessary to construct signals at any appreciable elevation above the high-water line. Almost any type of signal will

serve that can be identified from a distance of several miles. Where natural objects are not available, the most satisfactory and economic types of signals are those made of whitewash or white signal cloth. These show very distinctly against a dark background when direct sunlight is reflected from them, but will be visible only a short distance if they are in shadows or during overcast weather. Consequently, it is very important to dress the signals in direct contrast to the background, i. e., white against a dark background and black against the skyline, or a combination of black and white when the signal shows against a light background from one direction and a dark background from another. Red is the most satisfactory color to use against a background of snow, for a black target is easily confused with protruding rocks.

For marking stations and erecting whatever types of signals may be needed in any particular region, the stores of survey vessels should include ample supplies of unslaked lime, signal cloth, canvas, slats, lumber, cement, cast-iron soil pipes, wire, bolts, nuts, nails, tacks, tools, etc. Muslin signal notices (Form 51) shall also be carried and used wherever there is a likelihood of signals being disturbed or destroyed by persons unaware of their purpose.

Where stations and signals are to be established on private property in inhabited areas, permission must be obtained from the owner, and no damage to or defacement of property shall be made without his consent.

Where surveys are made along the shores of publicly owned areas, such as public parks, National or State forests, reservations, and wildlife refuges, the superintendent or other official must be contacted to explain the nature of the survey and to request his cooperation. This is especially important where marks are to be established, signals erected, or observing lines cleared through wooded areas. Satisfactory cooperation can usually be obtained when the nature of the work is understood, and arrangements can often be made to have one of the caretakers accompany the party for a day or two to approve the necessary clearing and help dispose of the resulting wood and brush. He may be hired for this purpose except when he is a federal employee.

Where signals are erected over marked stations, precautions must be taken not to disturb the station and reference marks.

For signal building, reference should also be made to Special Publication No. 234, Signal Building.

## 272. Tall Signals

Since the extensive use of buoys for offshore hydrographic control, the need for very tall signals has diminished during the last 10 years. In recent hydrographic surveys along low flat coasts, 40 feet has been about the maximum height needed to furnish ample control for distances of 5 to 10 miles offshore, from which limit the hydrography is extended by buoy control.

Of the types of tall signals used by the Coast and Geodetic Survey in the past, wooden structures approaching 100 feet in height were used very frequently, and portable steel towers of the same height were used occasionally. It is with these tall wooden structures that **272** and **2721** deal.

Infrequently, signals have been constructed for use in triangulation to heights of 200 feet or more, but these have not been to specifications as each one has been more or less of an individual case. These range from targets erected in the tops of tall redwood trees to towers made from bamboo poles. Other organizations have used various ingenious methods of erecting tall signals, one of which appears to have particular merit. The French have mounted clumps of cabbage palm leaves on the tops of tall tubular

steel poles for use in hydrographic surveys off low islands in tropic areas. The poles are in sections, each fitting into the other, and the height of a signal may be increased as desired by adding additional bottom sections, the poles being held upright by guys

For offshore ship hydrography, a signal must have an elevation great enough to overcome the curvature of the earth and be sufficiently large to be seen in a sextant at the required distance. The elevation above the water of the tower to be constructed can be computed from the formula:

$$D=1.15\sqrt{H}$$

or

$$H=0.75\,D^2$$

where $H$ is the height of the tower in feet above the water, 1.15 is an approximate constant for curvature and refraction, and $D$ is the distance in nautical miles at which the signal must be seen from the water level. Thus, the elevation of a signal to be just visible from the waterline 10 miles at sea would be 75 feet. Sextant angles are usually observed from the ship's bridge and assuming the height of the eye to be 23 feet above the water, then the same signal can be seen 5½ miles farther, or a maximum distance of 15½ miles. This extra distance of 5½ miles is computed from the same formula by solving for $D$, the value of $H$ being the height of the eye above the water.

In perfectly clear weather a signal, especially if it shows against the skyline, can be observed until it disappears below the horizon and often, just before disappearing, refraction actually makes it appear larger than it appears at a slightly closer distance. When the sea is rough, signals cannot be seen as far, by a considerable distance, as in calm weather, because of the waves between the observer and the signal.

Many different factors must be taken into consideration in determining the height and size to build an object to be seen the required distance, some of which are as follows: The background, whether wooded, open sky, or intermittent trees and sky, and whether the tree line is close to or far from the signal; the direction of the shoreline, and whether a signal will reflect the sunlight; and the prevalent weather, whether clear or cloudy and overcast. A much larger target is required if cloudy or overcast weather is prevalent or if the signals must be so placed that there is no reflection from the sun during the greater part of the day. If the background behind a white signal is intermittent woods, a much larger and more distinct signal is necessary, for a small one cannot be distinguished from an opening or break in the tree line.

There is little use in making any part of the target black unless it projects well above the trees or skyline, in which case the entire target should be black.

### *2721. Ninety-Eight Foot Signal*

The construction of a wooden signal of this type is started by building, on the ground, a quadrilateral section 16 feet high and 4 feet square, which is raised into place in a hole about 8 feet square and 6 feet deep, so that the entire base of the tower can be buried in the ground. The bottom braces are doubled (one inside and one outside the legs) and are extended about 2 feet beyond the sides of the structure. Scrap lumber or drift wood is laid across the bottom horizontal braces. It is important that the first section be set exactly vertical before the hole is filled and the building continued. Its verticality can be ensured by setting up and leveling a small theodolite and sighting up and down the sides of the signal with the vertical cross hair or by sighting along the string of a plumb bob suspended at arm's length from a position a little above the height of the eye. The structure is held in this vertical position by temporary guy wires while earth is tamped firmly around the base of the signal and the hole is filled.

Construction is then continued, the verticality of successive sections being checked in the same manner as the first section and more temporary guys used, if necessary, to pull the structure a little one way or the other. The scaffold is 4 feet square in its horizontal section, the legs and sides being parallel throughout its height. Horizontal braces are nailed to the tower at 4-foot intervals and diagonal braces nailed between these 4-foot sections. Leg pieces, braces, and guy wires are added until

the desired height is reached. Braces should be cut as needed so that allowance can be made for slight variation in cross section and the spacing of the horizontal braces. No attempt should be made to cut the lumber to dimensions and shapes on board the ship or before the signal is erected. To do so is a waste of time and lumber because the pieces cannot be made to fit correctly since signal building is not a precise engineering feat. The signal may not be started truly vertical or the sides and legs may not be precisely parallel. These defects can be remedied as the work proceeds if the lumber is cut as used, but cannot be remedied if dimensioned pieces are used because they will not fit.

The target is composed of 40 to 60 boards spaced 4 inches apart. These boards are ½ by 6 inches by 12 feet in size, joined in groups of three. Vertical strips 2 by 2 by 26 inches are nailed 2 feet from the outer ends of each group of target boards to serve as stiffeners and to which wires can be fastened to draw the ends of the target toward the landward side of the tower, so it will present a convex surface to seaward.

The target boards should be covered with two coats of paint or with signal cloth tacked on each board. Experience has demonstrated that white signal cloth reflects sunlight better than white paint. If the boards are painted, it should be done on board ship because ashore it is difficult to prevent sand or dirt getting on them before the paint is dry.

The guys are made of No. 8 galvanized iron wire. Four guys are placed at the 40-foot level, leading away from the four corners of the structure, each in a direction in line with the corner diagonally opposite. Eight guys are placed at the 60-, 80-, and 98-foot levels; four leading from the corners as at the 40-foot level, two leading seaward from the seaward corners, and two leading landward from the landward corners. The corresponding guys at the 40- and 60-foot levels are fastened to the same set of anchors. Likewise, the corresponding guys at the 80- and 98-foot levels are fastened to another more distant set of anchors. The directions of the guys may be varied for additional protection against the prevailing winds, but the greatest wind pressure is always against the target.

For anchoring the guy wires, timbers or deadmen are buried in trenches 3 feet deep which are dug 40 feet from the tower for the 40- and 60-foot level guy wires and 80 feet for the 80- and 98-foot level guy wires. An anchor timber should be not less than 4 by 4 inches by 8 feet in size. It is laid in the trench which is filled with earth up to the level of the top of the timber except in the center. Short pieces of lumber are then nailed across each end of the timber and the ends of the trench are filled in, leaving the middle open until the guys have been made fast. More pieces of lumber are then nailed across the middle part of the deadman and the trench is filled.

About 2½ days should be allowed for building a signal of this type and size, about half of the time being consumed in landing the lumber and other materials from the vessel and getting them to the site. This will naturally be the point of highest elevation in the immediate vicinity and may be some distance inland. The actual construction can be done very rapidly in fairly calm weather, especially if there are several experienced men in the party. It is practically impossible to handle the target boards in a moderate wind.

### (A) SPECIFICATIONS FOR NINETY-EIGHT FOOT SIGNAL

The specifications for the *98-foot signal* are as follows:

*Cross section.*—Four feet square.

*Height.*—Total 104 feet, the lower 6 feet being buried in the ground.

*Legs.*—Four by four inches, built up of 2- by 4-inch lumber, with joints overlapping at least 4 feet and strengthened by 1- by 4-inch by 3-foot pieces nailed over the splices.

*Horizontal braces.*—Two by four inches for the lower 16 feet and 1 by 4 inches above, spaced 4 feet apart.

*Diagonal braces.*—One- by four-inch boards cross-braced on the lower three panels; single and zigzagged above.

*Target.*—Of ½- by 6-inch by 12-foot boards in groups of three spaced 4 inches part, with 2- by 2- by 26-inch vertical strips to stiffen the outer ends and to which wires may be attached to arch the target.

*Anchors.*—Size 4 by 4 inches by 8 feet, built of 2- by 4-inch pieces, utilizing those with the most knots.

*Guy wire.*—No. 8 galvanized iron wire.

### (B) LIST OF MATERIALS FOR NINETY-EIGHT FOOT SIGNAL

| *Description* | *Size* | *Number required* |
|---|---|---|
| Lumber, S4S | 2″ by 4″ by 16′ | 80 pieces. |
| | 1″ by 4″ by 14′ | 120 pieces. |
| | ½″ by 6″ by 12′ | 40 to 60 pieces. |
| Lumber, scrap | 1″ by 12″ by 14′ | 6 pieces. |
| | 2″ by 2″ by 16′ | 4 to 6 pieces. |
| Wire, galvanized | No. 8 | 3,500 feet. |
| Miscellaneous | Paint and brushes or signal cloth and tacks. | |
| | Nails, rope, saws, hammers, shovels, etc. | |

### *2722. Forty-Foot Signal*

The type of construction of the 98-foot signal can be used to build hydrographic signals of various heights. The 16-foot base section is identical and the signal may be built up in sections to the elevation desired. For a 40-foot signal, guys are fastened at the 25- and 40-foot levels The target may be similar to that of the taller signal. If desired, one corner instead of a side of the scaffold may be pointed seaward. In such a case, the target boards are cut in 8-foot lengths and nailed on two sides to form a V whose apex points seaward.

Numerous types of signals can be built up to heights of 40 feet. The choice depends mainly on the quantity of lumber available, especially if there are no roads for transportation and all materials have to be landed from the ship. Pole signals constructed of 2 by 4's, in cross sections of 4 by 4 inches or 4 by 6 inches, with targets made from ½- by 6-inch boards, have been erected 40 to 60 feet high. Tripods 40 feet high have been erected, but generally lumber in lengths longer than 16 feet is required for the horizontal braces at the base. If native trees are available, pole tripod signals can be constructed. The various types of tripods can be dressed with whitewash, painted boards, canvas, or signal cloth.

### *2723. Ordinary Tripod Signal*

The ordinary tripod signal usually serves a dual purpose. It serves as a triangulation signal, being constructed in such a manner that an observer can set up his theodolite under the tripod and make observations without moving any of the structure. And it makes an ideal signal for inshore hydrography at distances of 3 to 5 miles, and even farther, if the elevation of the ground is sufficient and the tripod is properly dressed. (See fig. 43.)

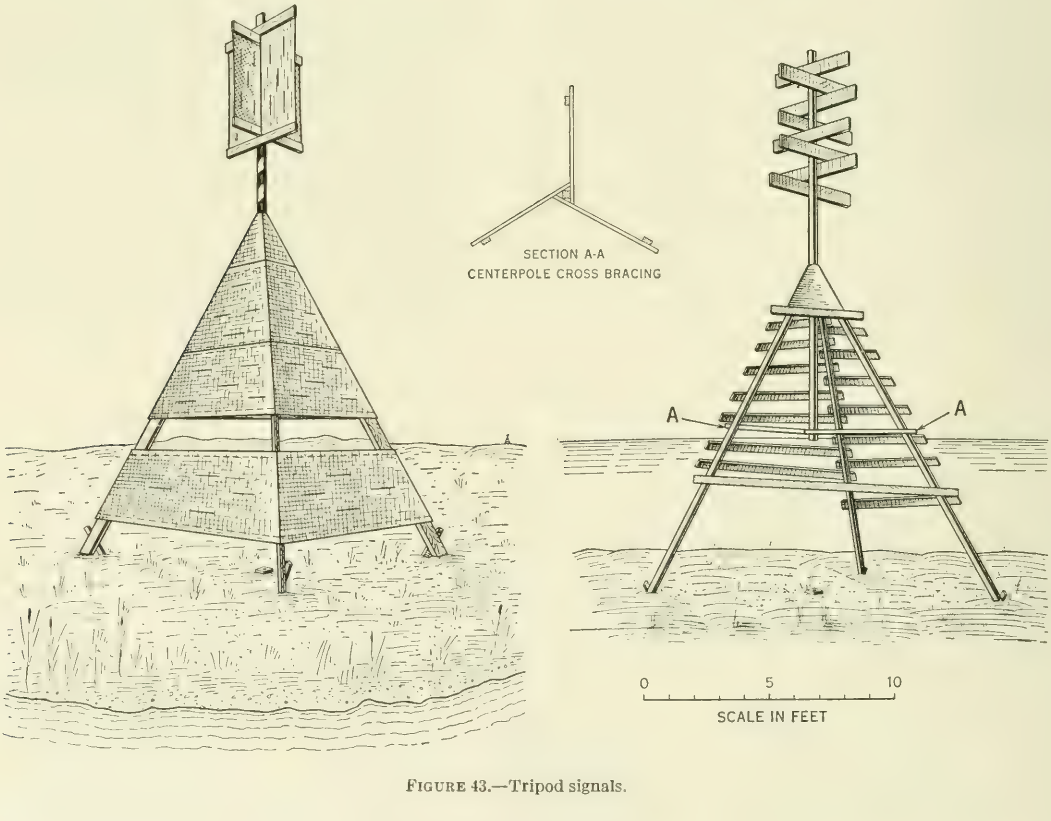


Figure 43.—Tripod signals.

To construct a tripod signal, three pieces of 2- by 4-inch by 16-foot lumber are selected for the legs and one 3- by 3-inch by 16-foot piece for the centerpole. The upper ends of two of the legs are sawed at an angle of approximately 35° so that they will fit snugly when the tripod is raised in place. Holes to take a ¾-inch bolt are bored near the upper ends of the three legs and about 8 feet from the lower end of the centerpole. The holes are bored through the 2-inch width of the legs, perpendicular to the sides of the unsawed leg but at an angle through the other two, so that they are approximately perpendicular to the sawed faces.

The target is next nailed on the centerpole. It may be either signal cloth tacked to wooden crosspieces, or eight ¼- by 6-inch by 3-foot slats. The portion of the centerpole between the target and the bolt hole is wrapped with white and black signal cloth. Four guy wires are then fastened to the top of the centerpole leading out through the crossed target. The legs and centerpole are then bolted together and placed flat on the ground with one leg pointing directly offshore.

If the station is to be occupied, the lower part of the centerpole will have to be sawed off about 6½ feet above the ground so the theodolite can be set up over the station mark and to provide head room for the observer without having to dismantle the tripod. If a 5-foot length is spliced to the bottom of the centerpole and a headless nail driven part way into the center of the lower end of the extension, the centering of the target can be quickly and easily performed, when the tripod is raised into place, by inserting the nail into the drilled hole in the center of the station-mark disk. This serves as a pivot while the centerpole is being plumbed, and when it is vertical, it is naturally centered at the same time. The plumbing may be accomplished by suspending a plumb bob at arm's length and alining the centerpole by eye along the plumb-bob string.

After the target has been centered over the station, the guy wires are secured, the centerpole is secured by cross braces to the legs of the tripod, and the tripod legs nailed to stakes driven in the ground. The seaward sides of the signal are then dressed with rough boards, spaced about the width of the boards apart, and whitewashed, if desired, or spaced about 2 feet apart with signal cloth securely tacked on to cover the space between. When signal cloth is used, it should be slashed with a knife to diminish wind pressure and to render the cloth useless for other purposes so that it will be less likely to be stolen. An opening should be left at the height of the telescope to permit observations to be made without having to tear loose any of the signal cloth (see fig. 43), but such an opening is unnecessary if boards are used, as one or two boards can be easily removed and restored to place after the observations have been made. After the construction and dressing of the tripod have been completed. the lower part of the centerpole should be sawed off at the desired height and the centering of the pole and target checked.

If the station is not to be occupied, a slightly different construction will be more convenient. The bolt hole should be bored in the centerpole 10 feet from the bottom, instead of 8 feet A headless nail is driven part way into the center of the bottom of the centerpole—a splice is unnecessary. The tripod legs should be about 13 feet long as the apex of the tripod need not be as high as is required for a station to be occupied. The tripod is then constructed and dressed as described above, except that no opening for instrument observations is necessary and the centerpole need not be sawed off. The bottom of the centerpole should be braced by 1- by 2-inch stakes.

Regardless of whether a tripod is constructed so as to be occupied or not, the guying and size of the lumber used for dressing depend mainly on the strength of wind prevalent in the particular locality. If strong winds are infrequent, the guy wires may be omitted entirely, especially if the tripod is exposed to livestock. For dressing, 1- by 6-inch boards are best as any smaller size is too light to support a man's weight on the longer lower sections. A nice dressing is made of 1- by 12-inch boards but the cost is high in comparison with 1- by 6-inch boards. Rough lumber is best for dressing as it is less expensive and will take whitewash better than surfaced lumber. Scrap lumber found on the beach can sometimes be used but its presence should not be relied on.

If strong winds prevail, the target should be constructed of eight ¼- by 6-inch by 3-foot slats spiraled around the top of the centerpole, and eight guy wires should be used instead of four, with the second set leading from the apex of the tripod. Signal cloth should be used for dressing instead of boards, so that in case of gales the signal cloth will be torn away rather than the entire tripod demolished. The signal cloth can be replaced easier than a new tripod can be built. The lower half of the signal cloth on a tripod should be tacked to pieces of 2- by 4-inch lumber rather than 1- by 6-inch boards. Even these have been broken in the center by violent storms frequently encountered in some areas.

(A) LIST OF MATERIALS FOR ORDINARY TRIPOD SIGNAL

| *Description* | *Size* | *Number required* |
|---|---|---|
| Centerpole, S4S | 3″ by 3″ by 16′ | 1 piece. |
| Target, of signal cloth | 1″ by 4″ by 3′ | 4 pieces. |
| or of slats | ¼″ by 6″ by 3′ | or 8 pieces. |
| Legs | 2″ by 4″ by 16′ | 3 pieces. |
| Braces for centerpole | 1″ by 4″ by 16′ | 1 piece. |
| For stakes | 2″ by 4″ by 16′ | 2 pieces. |
| Dressing for tripod: | | |
| for whitewashing | 1″ by 6″ by 16′ | 15 pieces. |
| or for signal cloth | 1″ by 6″ by 16′ or 2″ by 4″ by 16′ | 4 or 5 pieces. |
| Bolt, with nut and washers | ¾″ by 12″ | 1 each. |
| Guy wire (4 guys) | No. 8 or 10 | 4 lengths of 45 feet. |
| or 8 guys if needed | | or 4 lengths of 45 feet. 4 lengths of 30 feet. |
| Tools and equipment | Signal cloth or whitewash, nails, tacks, pliers, axes, saws, hammers, brace and bit, plumb bob, shovels, etc. | |

## 273. Steel Towers

Portable steel towers, identical with those designed for and used in first-order triangulation, have been used for tall hydrographic signals where they were needed at the same time for establishing triangulation control. For details of design and construction, see Special Publication No. 158, Bilby Steel Tower for Triangulation.

The towers are designed in 14-foot sections. This permits them to be dismantled and re-erected at other sites. The total height desired is gained by the addition or omission of the lower sections.

Transportation is an important factor in getting the steel for the towers to the station sites. A shore building party operating independently from the ship is most satisfactory. The steel can be landed from the ship in small boats if there is no other means of transportation, but this is slow work and pieces may be lost overboard.

For use as hydrographic signals, targets are necessary, either of canvas or boards bolted to the frame of the tower facing seaward. Since any type of target exposes a comparatively extensive surface to the wind, the tower should be guyed accordingly. Since the development and extensive use of buoy control for offshore hydrographic surveys, it is doubtful whether steel towers will be used by the Coast and Geodetic Survey for this purpose in the future.

## 274. Water Signals

Hydrographic signals must occasionally be erected in shallow water several miles from land. Numerous types of signals and methods have been successfully used. Some are partly constructed ashore, towed to the desired location, weighted down, and the construction completed. Others are entirely built in the water and still others are built on board vessels and lowered into place.

The United States Navy has constructed steel towers up to 100 feet in height in depths to 10 fathoms. The material used is similar to that of the Bilby steel tower but the structure is four- instead of three-sided. The three lower sections of the tower are constructed on the deck of the survey vessel and lowered over the side by the boat boom. With the tower suspended in the water from the side of the vessel, other sections are added until the tower rests on the bottom. The vessel is then backed away, the remainder of the construction being completed from motor sailers. The base of the tower is weighted with wooden mattresses filled with scrap iron. It can be guyed to

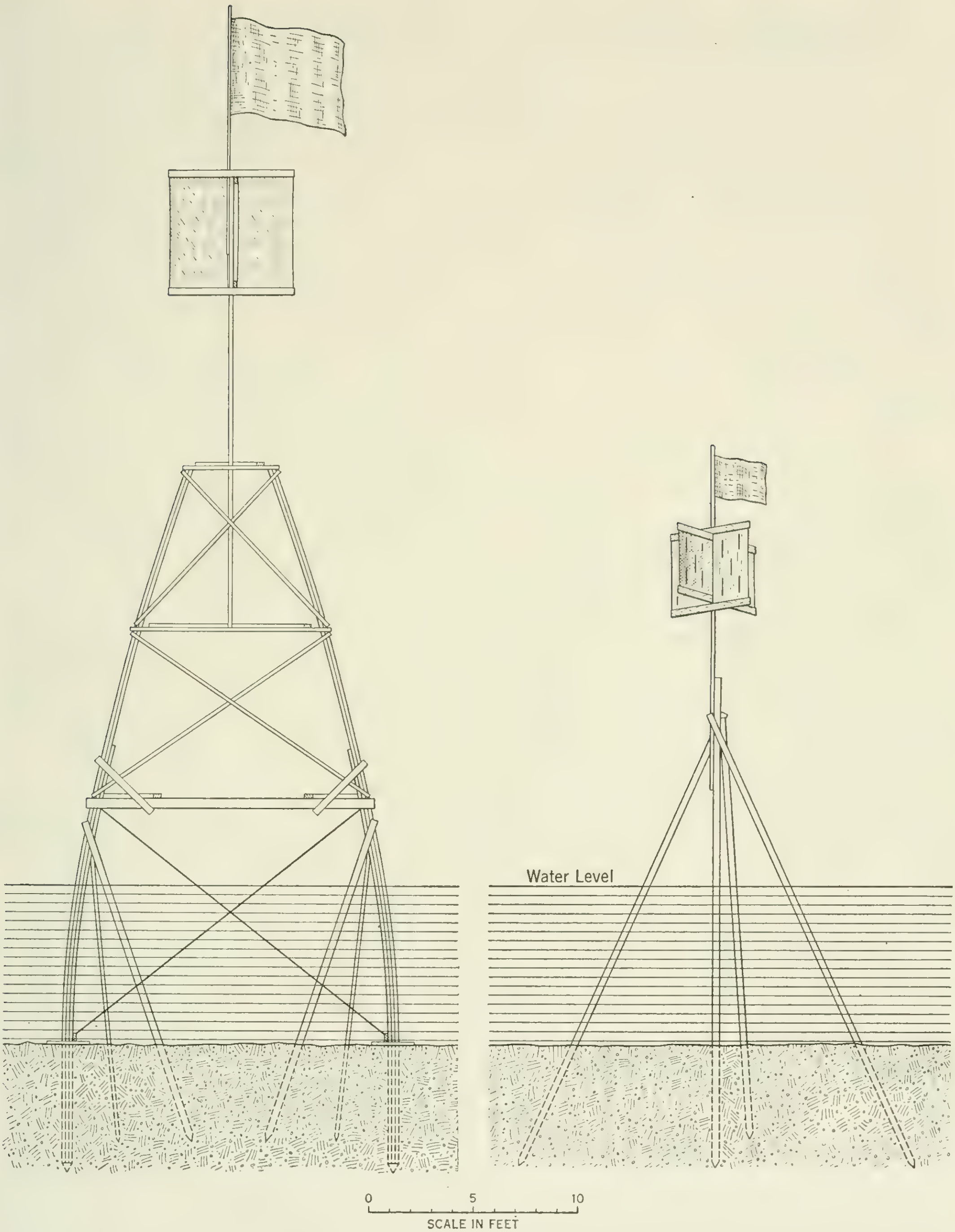


FIGURE 44.—Water signals. Left, a four-sided tower with flag 42 feet above the water. Right, a simple tripod with centerpole and banners.

anchors if necessary. Observations with a repeating theodolite can be made from the tower, if desired, when the sea is extraordinarily calm.

A simple tripod signal that will stand in a moderate depth of water may be made from lengths of iron pipe wired together through tee-fittings at their upper ends. When the exposed part is wrapped with cloth and flags are erected on top of it, it may be seen at a considerable distance. Such signals may be made more secure by pumping the legs into the bottom by means of a water jet. Where this is not possible, as in rocky areas, weights with wire loops around the pipes may be slid down the legs to secure them. Each pipe leg should be provided with a fitting near the bottom to engage the wire loop and hold the weight in place. Long poles and saplings have also been pumped into ocean bars by means of a water jet and have withstood moderate storms.

A type of water signal that is constructed on land and then towed out and sunk in position is described in detail on pages 35–38 of Special Publication No. 234, Signal Building. This type of signal has been used to depths of 13 feet.

The details of two wooden structures that have been used successfully for hydrographic control on off-lying shoals are illustrated in figure 44. One is a simple tripod with centerpole, crossed banners, and flag; the other is a simple four-sided tower with the top of the flag 42 feet above the surface of the water. The legs are jetted into the bottom by means of a double-action hand pump with a 2½-inch suction and 2-inch discharge, mounted in a launch in such a manner that four men can handle the brakes. A 2-inch fire hose is connected to the discharge end of the pump to which is added a length of 1½-inch iron pipe to act as a reducer. A short piece of ¾-inch pipe forms the nozzle.

When a signal is to be erected, the launch is moored in position by four anchors leading fore and aft and from each side. One of the legs of the structure is then held upright and the pipe is placed alongside it, with the nozzle held loosely alongside the bottom of the leg by a thin metal stop nailed to the leg. A 4- by 6-inch leg can be jetted into 6 feet of mud or loose sand in 5 minutes. After the legs are in place and the horizontal braces nailed to them, the men can mount the structure and complete it as if it were on land. If the bottom material is very soft it is best to nail crosspieces on the legs to prevent any of them from sinking deeper than desired.

Water signals of the above types may be located by any of the conventional methods. Theodolite observations from three triangulation stations are preferable, but if impracticable, sextant fixes or cuts should be obtained.

## 275. Signal Cloth

Signal cloth is used to dress signals to make them conspicuous and easy to identify. No color except white or black should be used on a signal which is to be observed from any considerable distance. The choice of color depends almost entirely on the background and the greater the contrast, the more distinctive will be the signal. Unless the signal is viewed against varying backgrounds from different directions, it is best to use only one color for a target—i. e., all black or all white rather than half black and half white. White is best against a dark or green background and black best against the skyline, water, or a light background. Red and orange may be useful as variations on signals to be used at close range, being especially effective against a background of snow or a glaring white beach. Black is objectionable on signals in the snow as it is difficult to distinguish from rocks or other black spots when viewed even at a short distance. White is valueless against the skyline unless the sun's rays are reflected from it.

White signal cloth is a superior reflector to either whitewash or white paint. A slanting surface is a better reflector than a vertical one, except in the early morning or late afternoon.

Reports from field parties indicate that the grade of white signal cloth available at Navy depots in 1941 is superior and more suitable for signal dressing than that purchased commercially. It is a tough material and withstands wind and weather well. It is described in the General Schedule of Supplies as Sheeting, Cotton, Gray, 36 inches in width, and is listed as Stock No. 27–*S*–7670. The cost in 1941 was about 6 cents per yard.

Signals are dressed with cloth in different ways. They should be varied in size and shape to avoid a similarity between adjacent signals. The most frequently used types are crossed banners, flags, cloth tacked on the bases of tripods, cloth tied on bushes, cloth wrapped around tree trunks and stumps, etc.

Target boards on tall hydrographic signals and slats on centerpoles have been whitewashed or painted black or white. If these boards are wrapped with white or black signal cloth the targets will have greater visibility, for cloth is a better reflecting surface and will not fade so rapidly. All large pieces of signal cloth should be pierced with random slits, 4 to 6 inches long, to serve as vents to ease the wind pressure and to discourage vandals from stealing the cloth for their personal use.

### 276. Whitewash

Whitewash, made from unslaked lime, is a convenient, economic, and satisfactory material with which to mark signals for inshore hydrography, especially where the coastline is rocky. Its use is not limited to rock surfaces, however. Boards on tripods, small buildings, driftwood, stumps, tree roots washed up on the beach, pieces of wreckage, and almost anything that will serve as a signal can be whitewashed to advantage. Even bluffs of crumbling dirt or disintegrated rock can be sprayed with good results.

Pulverized unslaked lime is usually sold in paper sacks or wooden barrels. When it can be purchased as required this is satisfactory. It deteriorates rapidly, however, and when a stock of it must be kept on hand for use over a considerable period of time, it should be purchased in watertight metal containers, each containing about 90 pounds.

Whitewash for marking signals is made by filling a bucket about one-quarter full with pulverized unslaked lime and adding about 1 gallon of water. As the mixture boils it should be stirred and a little water added from time to time to keep it from boiling over. When the boiling ceases, more water should be added while it is being stirred until it has a thick soupy consistency. The mixture should be stirred with a stick at least 3 feet long from a position as far away from the bucket as practicable because it is likely to spout up while boiling; it is not pleasant on the skin and is decidedly painful and may be dangerous in the eyes.

Whitewash is usually put on with a brush, but spray guns, similar in type to those used for spraying fruit trees, have been used very successfully. Their principal advantage is in whitewashing objects which cannot be easily reached with a brush, and in spraying rough or crumbly rock which cannot be coated thickly and evenly with a brush. They may also be used for spraying whitewashes on cliffs that rise almost vertically from the water where landings are difficult or impossible. The liquid must ee thinner than when a hand brush is used and must be strained before use to keep the hose and valve from becoming clogged. After use each day, the sprayer must be thoroughly cleaned with fresh water to wash out all whitewash and salt deposits.

Whitewash is most permanent when it is applied to a dry rock surface. It is a waste of time and effort to whitewash during a rain. Near the high-water line whitewash will soon be washed off or become so dim as to be indistinct and be confused with guano deposits. One bucket of whitewash is ordinarily sufficient to make a signal

that will remain in good condition for one season. It will usually be recoverable the following year but ought to be re-whitewashed if it is to be used to any appreciable extent. The shapes and sizes should be varied to make the signals distinguishable and easy to identify.

## 28. SURVEY BUOYS

Where buoy stations are required to control hydrographic surveys beyond the visibility of shore signals, they must be marked with a suitable buoy structure. A design for a buoy structure for use in a particular area depends largely on the character of the area and the visibility required. Shallow water at the station will limit the length of the underwater portion of the buoy structure. The strength of current, the prevalent weather conditions, and the depth of water are factors which influence the amount of buoyancy required in a buoy. The weight of the anchor and the weight and size of the buoy structure are limited by the ability of the ship's equipment to handle them when they are being anchored and weighed. The conditions influencing the size and design of buoys are likely to vary with different survey projects and the descriptions and specifications in this section should be considered general, subject to modification to suit the particular conditions encountered.

The general designs of buoy structures are influenced by a number of elements. Buoys are generally constructed on board ship by the ship's personnel and a simple design that may be made from readily acquired materials and with ordinary tools is necessary. The design must be such that the buoys may be built in the space available on board ship. They should be built of light but strong material—light for buoyancy and ease in handling, yet strong enough to withstand the strains and stresses to which they are subjected while being handled and during stormy periods while anchored. The design should allow for partial disassembly so that they may be easily handled and stored compactly on board ship. They should also be constructed of inexpensive materials that are commercially available and should not require parts of special design.

Buoys of various designs, embodying many unique ideas, have been constructed to meet the conditions encountered in various areas, but these designs have recently become more or less standardized. The buoy structures in most common use at present are described herein in some detail; others that are seldom used are included, but in less detail, for possible use in unusual circumstances.

Experiments with streamlined buoys have given promising results and their use is probably indicated where there are strong currents (see **2843**).

### 281. Buoys in General

The essential parts of a survey buoy structure are: One or more drums (or barrels) for buoyancy, which support a centerpole or light framework forming the body of the structure, on whose upper end is a target or flag to increase the visibility, and on whose lower end is a counterweight to hold the structure upright, and suitable ground tackle for anchoring. Each of these parts varies with the type of buoy and its intended use, and also with the material available for its construction. Only materials of good quality should be used to build buoy structures. It is poor economy to use cheap materials of doubtful quality that are likely to fail and result in the loss of a buoy after it has been placed on station and its position has been determined. The value of the ship time lost in replacing a single essential buoy is equivalent to the cost of the material for several buoy structures.

The kind of lumber to be used in buoy construction is limited by what is locally available. It should be a first-quality, straight-grained wood, free from knots and checks, light in weight but structurally strong, thoroughly air dried, either rough or surfaced. The best lumber available on the Atlantic and Gulf Coasts is Southern cypress, while Douglas fir and redwood are to be preferred on the Pacific Coast. Because the life of a survey buoy is comparatively short, common nails, and ordinary steel screws, machine bolts, and plates are used in its construction.

Standard commercial steel drums and barrels are used almost exclusively to give buoyancy to the buoy structures. The *returnable* or *nonreturnable* steel, oil, or gasoline barrels of 55-gallon capacity are generally used for ordinary buoy structures. A 65-gallon barrel, equipped with a bolted cover, is used in the East Coast sono-radio buoy, and a 55-gallon removable top, bilge barrel is used for the Vincent type. Steel barrels of various sizes down to 10-gallon capacities are used in combination with the larger barrels. These smaller barrels are also used in constructing small buoys. Spherical steel buoys of small size will be found useful for various field operations.

Recent experiments with buoys indicate that better buoyancy may be provided by a specially designed buoy (see **2843**). A single bare 55-gallon barrel anchored in 50 fathoms of water with the usual anchor cable has a reserve buoyancy of only 177 pounds and the Vincent sono-radio buoy without anchor cable has a reserve buoyancy of only 200 pounds. A relieving buoy should always be used to support the anchor cable of a sono-radio buoy in areas where there are strong currents—the reserve buoyancy is not sufficient to depend on in such cases.

The most essential feature of a drum or barrel for use in buoy construction is its watertightness. It should also be of strong but light construction so as not to add unduly to the total weight of the buoy. The use of a standard commercial product is an economy.

The ordinary crossed targets on a buoy structure may be made of signal cloth, ordinary screen-wire cloth, or board slats. Screen-wire cloth has been found to be more durable, black preferred for visibility. If black is not available, screen painted black is satisfactory. Flags and large banners are made of a suitable grade of cloth. Colors in varying combinations are used to identify the buoys. The banners, flags, and targets are constructed to be attached to the buoy at the last moment, and to be readily detached when it is brought aboard, to facilitate stowage in a smaller space. Where subtended vertical angles (see **3363**) may need to be observed on buoys, all crossed banners on either survey buoys or sono-radio buoys should be placed at a known height above the waterline.

The counterweights may be any heavy metal pieces of small bulk procured from junk yards. The total weight of the counterbalance required depends on the size and design of the buoy. For the standard one-barrel buoy, a single railroad car coupler, weighing from 180 to 200 pounds, is most satisfactory. A precast concrete shape of suitable size and weight may also be used. The counterweight should be made to be readily attached and detached from the buoy structure.

Buoys are painted to afford greater visibility and for preservation. The superstructure above the barrels is generally painted with a good grade of exterior paint, the color to be used being selected to afford the greatest visibility; in hazy atmosphere white will generally prove best, while red or black is best where clear atmospheric conditions prevail. The barrels and all of the underwater parts of the buoy are generally painted with either red lead or antifouling paint.

### *2811. Different Types of Buoys*

Buoys of various types and sizes may be required in the different survey operations, and various buoyancies are needed to support the anchoring gear depending on the depth of water. A survey buoy may vary from an ordinary 5-gallon can or sphere, or a single barrel with no superstructure, to an elaborate buoy structure constructed of four standard 55-gallon barrels. There are at least seven different types of buoys for ordinary use. These are: (1) Small marker buoy with no superstructure, (2) small buoy with target used by launches and auxiliary vessels, (3) shoal-water buoy, (4) standard one-barrel buoy, (5) two-barrel buoy, (6) three-barrel buoy, and (7) four-barrel buoy. There are two types of structures for sono-radio equipment: one is a wooden frame built around one or more steel barrels, and the other is an all-metal construction using a single steel barrel.

### *2812. Various Uses of Buoys*

In addition to their general use for the control of extensive areas in offshore surveys and as R.A.R. stations, buoys are used for other purposes in connection with hydrographic surveys. As a marker buoy, anchored at the approximate center of a shoal or reef, a buoy furnishes a leading mark for a system of radiating lines for the close development of the area. It is especially useful for this purpose in areas where there are no ranges that can be used in running the lines. Where there are strong currents, the least depth on a small shoal or rock can scarcely be found without the use of a marker buoy. In unsurveyed areas a buoy may be used as a temporary aid to navigation to mark a submerged rock or dangerous shoal while the survey vessel is operating in the vicinity, or until it can be more permanently marked by the United States Coast Guard. In R.A.R. surveys, in addition to their use for control, buoys are often used as references for important positions.

### *2813. Lights for Buoys*

Survey buoys must often be anchored near shipping lanes where they may be run into, especially at night. Although notices of survey buoys are published in the "Notice to Mariners," nevertheless losses occur. An inexpensive flashing light installed on a buoy minimizes such losses. Such lights are also useful for tying a long dead-reckoning line to control after nightfall, and for finding buoys to be serviced or picked up at night.

Various commercial companies manufacture simple, inexpensive lighting apparatus which may be adapted for use on buoy structures. The total weight of the apparatus must be a minimum to avoid making the buoy top-heavy. The light should be visible for a distance of at least 1½ miles and should operate for a long period on a minimum supply of electric current. A waterproof installation is required since the apparatus is mounted outside the barrel on the superstructure of the buoy. A waterproof box, containing the batteries and flasher unit, should be mounted on the lower part of the superstructure but high enough above the top of the barrel so that it will not be constantly submerged at any time. A waterproof fixture containing the light should be mounted at the top of the buoy structure so as to be visible in all directions.

A satisfactory light bulb for use in the assembly is an "Amglo Batrilite No. 75–*C3R*," manufactured by the Amglo Corporation of Chicago, Illinois. It has a characteristic neon color. The bulb

is made to be used in a standard four-prong radio tube socket and it should be mounted under a standard watertight launch masthead fixture. An "Eveready Luminous Tube Operating Unit," manufactured by the National Carbon Company has been found a very satisfactory flasher unit This type of flasher unit is made in three different models, classified according to the flashing frequency. These are for 80, 200, or 400 flashes per minute which will operate for 110, 100, or 40 days, respectively, when supplied with current from a 6-volt *hot-shot* battery. The flasher unit is permanently sealed and it must be mounted in an upright position for the switch to operate efficiently. The Amglo Corporation also manufactures a flasher unit called "Flasherpak." The flasher unit and battery may be contained in a watertight box whose inside dimensions are 6 by 8 by 18 inches. Exterior connections must be made with waterproof cable, such as "Tyrex."

### *2814. Buoy Identifying Marks*

For identification during field operations, the name of the station is painted on the superstructure of each survey buoy or on a piece of signal cloth tacked thereon. In addition, ordinary survey buoys (not sono-radio buoys) may be identified by flags of various colors used in various combinations attached to a short staff at the top of the buoy superstructure. Sufficient combinations of three colors are possible so that no two buoys in a locality will have the same combination.

Identifying flags on survey buoys are of particular value in starting a sounding line. The stations may be identified from a distance so that it is not necessary to maneuver close to them in order to read the names. The flags also aid in identifying a drifting buoy seen during survey operations.

A sono-radio buoy is marked with the name of the R.A.R. station but flags should not be used. Each should be marked with a sign, however, warning vessels to keep clear. These signs are made of baked enamel on a metal base and are designed to fit on the wooden buoy structure. They contain a legend, "Survey Buoy, KEEP OFF, Property of U. S. Coast and Geodetic Survey," that not only serves as a warning to fishermen and curious yachtsmen, but also aids in the recovery of the apparatus if the buoy should go adrift. These signs may be obtained from the Washington Office on request. Ordinary buoys may be marked with the same sign or, if they are not, they should be marked with a muslin "Signal Notice" (Form 51) tacked to the wooden superstructure.

## 282. BUOY CONSTRUCTION

### *2821. Small Marker Buoy*

A 5-gallon gasoline (or oil) can, anchored by a light line or piece of stranded sounding wire attached to a small anchor or grapnel, makes an admirable small marker buoy for a launch hydrographic party. Such a buoy is light, occupies little space, and is entirely satisfactory for temporary use in marking a shoal or other area during investigation. Any suitable object, a life ring or cork life preserver, may be substituted for buoyancy.

If additional visibility is required, the 5-gallon can may be secured to a light pole, 5 to 8 feet long, with a flag on the upper end and a counterweight on the lower end. Such buoys have withstood heavy weather, and they are much more easily sighted from a distance.

Small spherical buoys, or 55-gallon barrels without superstructure, anchored with the same ground tackle used for survey buoys, are frequently needed for marker buoys in R.A.R. or buoy-control surveys. The 18-inch spherical buoy used in mooring seaplanes or small yachts is convenient and will generally have sufficient buoyancy to hold the weight of the anchor cable without submerging. Such buoys, without superstructures, are difficult to see at a distance and should be painted a bright yellow, or white, to increase their visibility. Suitable rope loops should be rigged on top of them into which a hook may be inserted when they are being lowered or raised over the ship's side. (See also **2835**.)

### *2822. Small Buoy*

The smaller auxiliary vessels frequently require buoys to control offshore hydrographic surveys but the standard survey buoy cannot be handled by their limited equipment. For such use a miniature of the one-barrel buoy (see **2824**) may be constructed. A 10- or 20-gallon barrel is substituted for the 55-gallon barrel and all other parts are made correspondingly light for ease in handling. The design of the small buoy should be similar to that of the standard buoy but lighter lumber should be used and the counterweight should not exceed 35 pounds in weight. The over-all length of the small buoy structure should be about 15 feet, the small barrel being 8 feet above the lower end. A 10-foot staff with target flags is secured to the upper part of the buoy structure to increase the over-all height of the buoy, when afloat, to about 16 feet. The counterweight is shackled to an iron plate which is bolted to the lower end of the wooden structure.

### *2823. Shoal-Water Buoy*

Buoy control may be required in extremely shoal areas where the long submerged part of a standard one-barrel buoy might ground in the shoal water. A special buoy structure, with a short submerged section, is required in such a case.

The shoal-water buoy is built by enclosing a 55-gallon steel barrel in a short square wooden frame from which a mast extends. Two frames, about 10½ feet long, made of 2- by 4-inch lumber, are crossed at right angles around the steel barrel, extending 5 feet above the top but only 3 feet below the bottom of the barrel. Each frame is secured to the barrel by two iron rods bolted through the frame, one just below and one just above the barrel to hold it firmly in the structure. One end of one of the upper iron rods is made with a 2-inch eye to which the anchor cable may be attached.

A 10-foot mast is stepped on the top of the barrel and secured vertically to two pairs of 1- by 4-inch cross braces at right angles to each other at the upper end of the barrel and two similar pairs of cross braces at the top of the framework. Crossed banners of suitable size and material are added to the top of the mast.

To reduce the draft of the buoy the counterweight is incorporated in the buoy structure. The lower end is built as a box form, which includes the lower 20 inches of the framework, into which sufficient concrete is poured to furnish the desired counterbalance.

### *2824. One-Barrel Buoy*

The use of the one-barrel buoy has become practically standard in buoy-control surveys. It is simple to construct, economic in cost, and its size and height are sufficient to be seen at the required distance. The design has developed from many years of field experience in building buoys on shipboard. It can be constructed and stowed in the limited space available and its lightness gives it buoyancy and makes it easy to handle when it is being anchored or weighed.

### (A) SPECIFICATIONS FOR ONE-BARREL BUOY

The one-barrel buoy, illustrated in figure 45, consists of a 55-gallon oil or gasoline barrel secured in a frame of 2- by 4-inch lumber, cross braced with 1- by 4-inch lumber. Either finished or rough lumber may be used; the former is more easily handled and painted but the latter is stronger by reason of its greater cross section. A *nonreturnable* barrel is secured in the frame by two cross braces, grooved to fit over the chimes of the barrel, and a half-inch bolt between the vertical frames at the top and bottom of the barrel as shown in the figure. If the heavier *returnable* barrel is used, the cross braces fitting over the chimes may be dispensed with, but the I-bar hoops of the rolling tracks must be cut out on opposite sides so that the vertical frame will fit flush against the barrel. The recesses thus formed will serve to hold the barrel securely in the frame without further bracing.

The lower end of the buoy is fitted with suitable fixtures to which a counterweight may be attached. An iron washer plate is placed on each side of the vertical frame and an iron counterweight plate between the frame members, all of which are held together by two half-inch through bolts. Three holes are drilled in the counterweight plate to take the two half-inch bolts and a three-quarter inch shackle which is used to attach the counterweight to the buoy. A railroad car coupler weighing 180 to 200 pounds is generally used for the counterweight, but any iron mass or cast concrete shape of small bulk and equivalent weight in water may be substituted.

A mast, at the top of which are nailed crossed banners 3 feet square, is incorporated in the superstructure of the buoy, surmounted by a flagstaff from which flutter flags of various numbers and colors which serve to identify the buoy. The banners and flagstaff are nailed to the mast with small nails so that they may be easily removed. A small piece of signal cloth, on which the name of the buoy station is painted, is tacked on each side of the superstructure.

A three-quarter inch eyebolt is bolted to one of the vertical frames at a position about 1 foot below the bottom of the barrel, and to which the anchor cable is attached. The exact position of the eyebolt is chosen so that the buoy will maintain as vertical a position as possible in the prevailing wind and current. To prevent the buoy structure from canting, the eyebolt should be placed higher for use where strong winds prevail than for areas where only strong currents prevail.

A rope sling is fitted on the opposite side of the buoy from the eyebolt, by which it is lowered into the water in anchoring and hoisted from the water in weighing. This rope sling is made of 3-inch Manila rope secured to the vertical frame just below and just above the barrel by means of double half hitches and lashings. After the buoy has been in the water a short time, the salt will stiffen the rope so it will stand out from the frame in a position to be engaged by a hook or grapnel. Being on the opposite

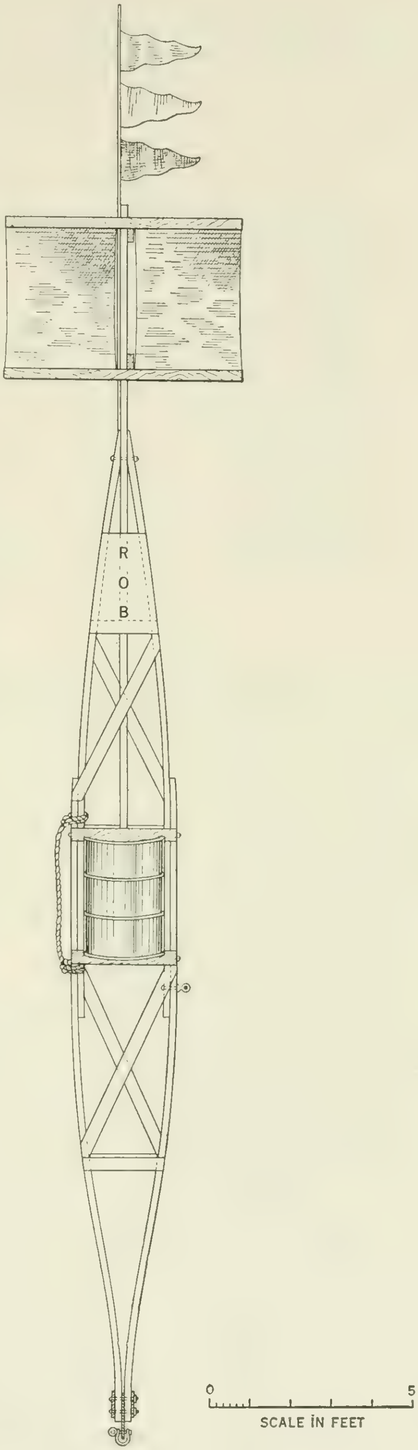


FIGURE 45.—One-barrel survey buoy

side from the anchor cable, the rope sling also serves to indicate the direction of the current as the ship approaches the anchored buoy.

#### (B) LIST OF MATERIALS FOR ONE-BARREL BUOY

| *Description* | *Size* | *Amount required* |
|---|---|---|
| Lumber (see 281) | 2″ by 4″ by 16′ | 5 pieces. |
| Do | 2″ by 4″ by 10′ | 1 each. |
| Do | 1″ by 4″ by 16′ | 4 pieces. |
| Barrel, G. I. | 55 gallon | 1 each. |
| Car coupler (scrap) | 180 to 200 pounds | 1 each. |
| Eyebolt with shoulder and nut, G. I. | ¾″ by 5″ | 1 each. |
| Bolts | ½″ by 7″ | 3 each. |
| Rods, tie, threaded on both ends | ½″ by 32″ | 2 each. |
| Nuts, hexagonal | ½″ | 7 each. |
| Washers | 1¼″ by 3/16″ (9/16″ hole) | 7 each. |
| Washers | 2¼″ by 3/16″ (13/16″ hole) | 2 each. |
| Washer plates, iron | 3″ by 10″ by ¼″ drilled | 2 each. |
| Counterweight plate, iron | 3″ by 15″ by ½″ drilled | 1 each. |
| Shackle, G. I. | ¾″ | 1 each. |
| Screen, wire, black | medium mesh, 1 yard wide | 2 yards. |
| Cloth, muslin, various colors | 1 yard wide | 2 yards. |
| Rope, Manila | 3″ | 15 feet. |
| Nails | 12 d. and 20 d. | |
| Tacks | carpet. | |
| Standard enameled buoy plate or muslin signal notice | | 1 each. |

#### (C) METHOD OF CONSTRUCTION, ONE-BARREL BUOY

The one-barrel buoy is designed so that it may be built on board ship, including the special parts required; washer plates, counterweight plate, and threaded rods.

A clear deck space approximately 35 feet long is needed, and two sawhorses, or boxes, are required to support the buoy frame while it is being built.

The first step in the construction of the buoy is to prepare the two vertical frame members, each of which is made of two 16-foot pieces of 2- by 4-inch lumber. Each pair is spiked together with a 5- or 6-foot overlap, so that the overlapped length will extend 12 to 18 inches above and below the barrel when the frame is attached. The two pieces of lumber must be in alinement when they are nailed together in order to obtain a symmetrical construction. Two 9/16-inch holes are drilled through the overlapped portion of each frame member through which to insert the two tie rods, one just above and one just below the barrel which is placed between and with its axis parallel to the frame members.

On the sawhorses, with the barrel between the two vertical members, the two tie rods are inserted with washers and nuts on both ends and the nuts are drawn tight to hold the barrel firmly in the center of the frame. Two wooden cross braces of 1- by 4-inch lumber, grooved to fit over the chimes of the barrel, are next nailed between the vertical members, two at the top and two at the bottom of the barrel. These serve to hold the barrel in place and prevent it from slipping out.

The upper and lower ends of the projecting vertical members are next drawn together by long wood clamps. This must be done carefully so that their junctions are on the centerline of the frame. The lower ends are sawed off evenly and two 9/16-inch holes are bored through them to correspond to the holes in the washer plates. The washer plates are placed outside and the counterweight plate between the vertical members and the bolts are inserted and drawn tight. The upper ends of the vertical members are trimmed to equal length and beveled to fit the mast which is placed between them. A 9/16-inch hole is bored through the three pieces of lumber at this point and a bolt inserted and drawn tight.

The clamps may now be removed and horizontal cross braces of 1- by 4-inch lumber are nailed on both sides of the frame 5 feet above its bottom and 4 feet below its top. Crossed diagonal braces, one brace on each side, of 1- by 4-inch lumber are nailed on the upper and lower parts of the frame between the horizontal cross braces and the barrel. The upper diagonal braces are also nailed to the mast which is stepped on the top of the barrel and nailed to the cross braces previously placed there.

The eyebolt is inserted through a 13/16-inch hole bored through one of the vertical members of

the frame, preferably at a 4- by 4-inch section, below the bottom of the barrel. The rope sling is placed on the opposite vertical member as previously explained in (A) above. Banners are made of wire screen tacked to 1- by 4-inch lumber, but neither the banners nor the flagstaff are nailed to the mast at this time. They are affixed just before the buoy is anchored to avoid damaging them while the buoy is being handled and to conserve stowage space.

### *2825. Two-Barrel Buoy*

Although the standard one-barrel buoy is used almost exclusively for buoy control there are occasions when additional buoyancy is required to counteract strong currents, deep water, or strong prevailing winds. This is attained by the use of an additional steel barrel, the two being utilized in any one of several ways.

The two barrels can be mounted vertically one over the other within the framework as illustrated in *A*, figure 46. The over-all length of this buoy structure and the general details of construction are the same as for the one-barrel buoy, the sketch showing only the details that are different. The increased distance from the top of the upper barrel to the bottom of the lower barrel causes additional strain on the vertical members where bent, and they must be reinforced with iron straps. The straps are made of 2- by ⅜-inch flat stock, drilled with holes as shown in the sketch. The barrels, if *non-returnable* ones are used, are held in place by tightening the tie rods, fitted with washers, so that the barrels will be held firmly between the vertical wooden members. If *returnable* barrels are used, they are held in place by slots burned out of the rolling tracks into which the vertical members fit, as

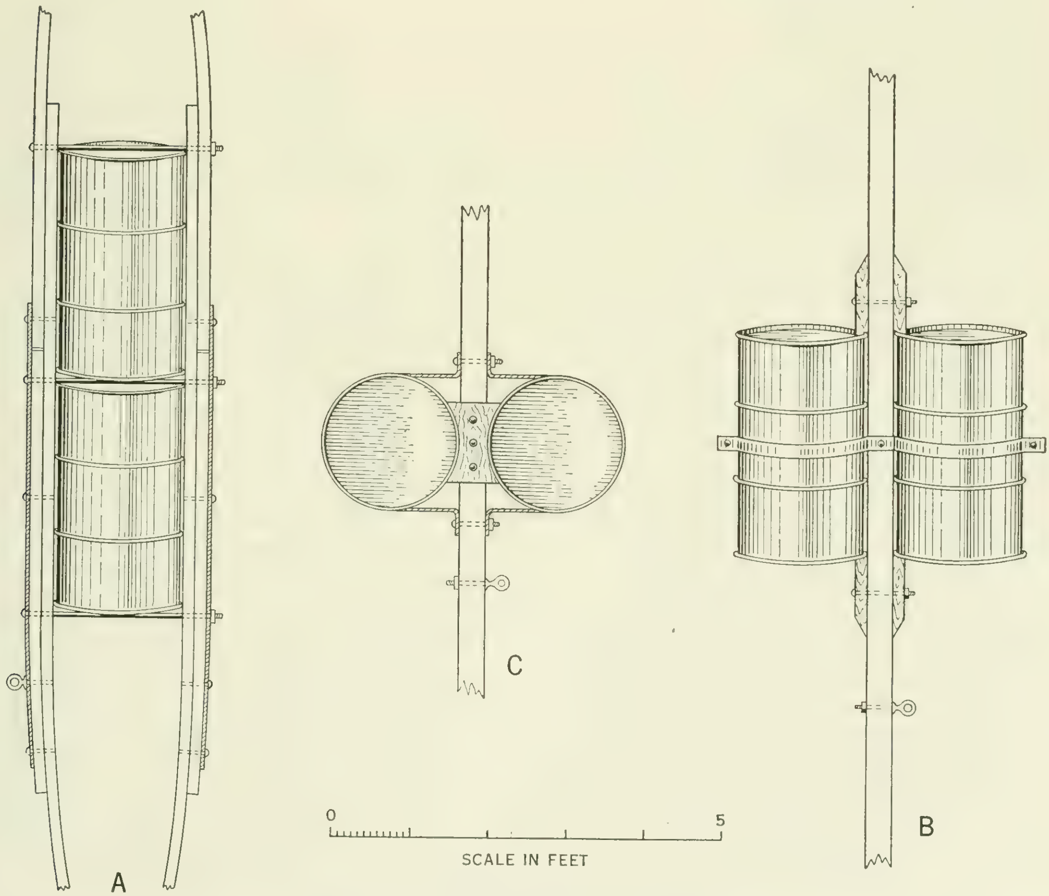


FIGURE 46.—Two-barrel survey buoys—three arrangements.

described for the one-barrel buoy. The additional buoyancy provided by the two barrels will permit the use of a heavier counterweight. One weighing 450 or 500 pounds will provide adequate stability and with it the buoy will float with about one-half of the upper barrel above the surface of the water.

Two methods of attaching two barrels to a single-pole buoy structure are shown in *B* and *C*, figure 46. Iron bands, bent to fit around the barrels, are used to hold the barrels to the centerpole. The centerpoles for these structures are made of rough 2- by 4-inch lumber spiked together to form a 4- by 4-inch cross section, except for the uppermost 8 feet. In the scheme represented in *B*, figure 46, the barrels are held more firmly in place by wooden lugs made to fit over the chimes of the barrels at top and bottom. One bolt through the centerpole is used to hold each pair of lugs in place. The construction represented in *C*, figure 46, requires two wooden blocks, one to fit on each side of the centerpole. These blocks are cut from 2-inch lumber approximately 6 inches wide with their opposite sides shaped to fit the curve of the barrels and are secured to the centerpole by wood screws or through bolts.

**(A) ADDITIONAL MATERIALS FOR TWO-BARREL BUOY**

(Arrangement A in fig. 46)

| *Description* | *Size* | *Number required* |
|---|---|---|
| Lumber | 2″ by 4″ by 12′ | 1 each. |
| Barrel, G. I. | 55 gallon | 1 each. |
| Rod, tie, both ends threaded | ½″ by 32″ | 1 each. |
| Nuts, hexagonal | ½″ | 2 each. |
| Washers | 1¼″ by 3⁄16″ (9⁄16″ hole) | 2 each. |
| Strap, drilled for ½″ bolts as shown | ⅜″ by 2″ by 6′ | 2 each. |
| Bolts, with nuts and washer | ½″ by 5″ | 7 each. |
| Counterweight of car couplers or scrap iron | 450 pounds total. | |

### *2826. Three-Barrel Buoy*

Three-barrel buoys have been used in the past. Their use is not recommended under ordinary circumstances because their larger, more cumbersome size makes them more difficult to build and to handle on board ship. The three-barrel buoy does carry larger banners which result in somewhat better visibility, but a heavier counterweight, heavier anchor, and stronger anchoring gear are required.

Three 55-gallon barrels and a 4-inch square centerpole, 23 feet long, are used to construct the buoy. Two of the barrels are laid side by side on their bilges and temporarily secured. The centerpole is placed on top and parallel with the barrels, with two of its sides tangent to their bilges and 8 feet of its length projecting above the tops of the barrels. The centerpole is then trimmed slightly so that, when the third barrel is placed on top and parallel to the lower two, it rests on them and the trimmed pole simultaneously. The three barrels are tightly bound together at each end with several turns of ⅛-inch galvanized wire cross lashed in the three spaces between barrels and made tight with Spanish windlasses.

Wooden wedges are driven between the barrels and the centerpole to prevent movement of the barrels along the centerpole. Four pieces of 2- by 4-inch lumber, long enough to extend 6 inches beyond the edges of the barrels, are notched to fit the chimes of the barrels. Two of these, crossed at right angles, are nailed to the centerpole just above the barrels, and two just below, and the projecting ends are tightly lashed with wire from top to bottom.

A 2- by 4-inch mast, 13½ feet long, on one end of which are crossed wire-screen banners, is spiked to the centerpole with an overlap so that the top of the banner is 16 feet above the top of the barrels.

The centerpole is braced by four pieces of 2- by 4-inch lumber extending diagonally from its upper end to the outer ends of the cross braces at the tops of the barrels. The mast is also braced by four pairs of galvanized guy wires, each tightened by a Spanish windlass, extending from about the middle of the crossed banner to the outer ends of the cross braces. The centerpole below the barrels is braced by four 2- by 4-inch by 6-foot diagonals to the lower cross braces.

Crossed banners as large as 6 by 8 feet in size may be used, but then a counterweight of at least 700 pounds is required even for ordinary conditions of wind and current. The counterweight should be attached by suitable fittings to the lower end of the centerpole, so that it is readily detachable.

### *2827. Four-Barrel Buoy*

The four-barrel buoy, which has been used to some extent in the past because of its greater range of visibility, is essentially a float, made of four 55-gallon barrels, on which is stepped a mast supporting a flag and four skirt banners.

The float is made of two crossed frames, each of which has an upright barrel at each end, which are bound together at their centers. Each cross frame is made of four pieces of 2- by 4-inch lumber 24 feet long, two pieces on top and two on the bottom of the barrels. The pieces are spaced 12 inches apart horizontally by crosspieces and the upper and lower pairs are bolted to one another by four suitable iron rods at each barrel, spaced so as to enclose it, two on each side. The ends of the crossed frames are lashed to one another by 2-inch Manila rope to form a rope square around the float at the top and bottom of the barrels. At the center of the float the crossed frames are secured to one another by metal straps bolted around the 2 by 4's where they cross, both at the top and bottom. A 4- by 4-inch mast 36 feet long is stepped in the vertical space between the frames and braced by four diagonal guys from the middle of the mast to the outer corners of the float near the barrels. A large black flag is attached to the upper part of the mast and below the guys four triangular skirts of white signal cloth are tacked to the mast, the diagonal sides of which are lashed to the four guys.

It is difficult to anchor and weigh this buoy with the gear usually available, and awkward to stow it on board ship unless the several parts are made so that they can be disassembled.

## 283. ANCHORING GEAR

The ground tackle used to anchor or moor buoys should be heavy enough to prevent their dragging or the anchor cable parting during periods of heavy storms; but the anchors should not be so heavy or massive that they will be difficult to handle on deck or the anchor cable too heavy to be supported by the buoy. The choice of an anchor depends on the material available, the holding quality of the bottom, the type of buoy structure used, the handling gear available, and the depth of water at the anchorage position.

The anchoring gear used with sono-radio buoys is the same as for ordinary buoys, except that precautions must be taken to make all connections tight in order to eliminate noises that might be *picked up* by the sono-radio buoy hydrophone. When a relieving barrel is used the length of chain between it and the buoy structure is usually passed through a section of discarded rubber water hose to dampen the clanking of the chain.

### *2831. Anchor*

Where they may be procured, junked railroad car couplers (drawheads) are standard equipment for use as counterweights and anchors. Used as anchors they have excellent holding qualities; they are convenient in size and weight for handling and, if available, can be purchased at junk prices. One car coupler weighs from 180 to 300 pounds, depending on the type. One coupler serves as the counterweight for the one-barrel buoy and, with the addition of a small piece of pig lead, will serve for the East Coast sono-radio buoy. Several car couplers may be joined together for use as an anchor. For average holding bottom, three car couplers furnish enough weight (550 to 900 pounds) to anchor the one-barrel buoy. The three car couplers are laid side by side and fastened together into one unit by a half-inch iron rod inserted through the holes at the coupling-pin end. The ends of the rod are bent around the couplers with a sledge hammer. The lower end of the anchor cable is shackled to this rod. The other ends of the couplers are lashed together with old pieces of heavy Manila rope, which also prevent them scarring the deck of the ship when they are moved about.

There are two general types of railroad car couplers, one incorporating a heavy steel spring used on passenger cars, and another without spring used on ordinary freight cars. The latter are shorter, stow better on deck, and are recommended when a choice is available.

Junked car couplers are frequently available only at ports with extensive railroad yards. At other ports other material will have to be substituted. A suitable anchor may be made from condemned anchor cable. A 750-pound anchor may be made from 7½ fathoms of 1¼-inch chain, faked in lengths of about 4 feet and securely wired together to form a solid mass. This forms an anchor that is easily handled and, because of its many irregularities, has good holding qualities.

An anchor or counterweight may also be cast from concrete, but a mixture of cement, sand, and gravel only has too light a specific gravity. A mixture of one part cement and two parts sand should be used as a binder to hold together solid pieces of scrap iron to furnish the desired weight. A concrete anchor is usually cast in a square-shaped block in which an inverted U-shaped rod is embedded to which the anchor cable may be attached. A 12- by 12- by 26-inch form filled with 300 pounds of scrap or pig iron cast in concrete in this manner will weigh 450 pounds. This size is suitable for the counterweight of the two-barrel buoy. Two grommets of 4-inch Manila line should be spliced tightly around the block to serve as skids when the block is moved around the deck.

Danforth anchors have recently been used successfully to anchor survey buoys. The Danforth anchor is a patent anchor of new design intended principally for use in anchoring yachts and motorboats. It is claimed to have a much superior holding power for its weight than other anchors of conventional design. The manufacturer claims a holding power of 200 or more pounds per pound of anchor weight. The anchors are made of cast alloy steel or nickel-chrome steel in sizes from 15 pounds up. The manufacturer is R. S. Danforth, Berkeley, California; other manufacturers make anchors of similar design.

The design makes the anchor self-burying in mud or sand bottom, where its use would seem to be most advantageous. One survey party substituted 30-pound Danforth anchors for 750-pound car-coupler anchors on two survey buoys and reported that they held through 50-mile gales. That survey party enthusiastically recommends their use.

### *2832. Wire Rope and Chain*

The anchor cable with which a buoy is anchored is generally a combination of wire rope and chain, but variations in the types and sizes of these are necessary in various depths of water. In general, a larger diameter cable may be used for buoys anchored in shoal or moderate depths because they do not have to support such a long length of it.

Chain should be used for that portion of the anchor cable adjacent to the anchor, which will chafe on the bottom. It is generally also used to join a relieving buoy to the buoy structure, if the former is used. Satisfactory results have been obtained with ⅜-inch galvanized boat chain and its use has become almost standard for this purpose.

In order to keep the weight of the anchor cable at a minimum, galvanized wire rope is used extensively. The two sizes in general use are ⅜-inch and ½-inch diameter, both of 6 strands of 37 wires each of extra strong cast steel.

In general, the anchor cables of buoys, anchored in depths of 20 fathoms or less, may consist of ⅜-inch chain exclusively. In moderate depths, to 50 or 60 fathoms, the

cable is composed of half-inch wire rope with a section of chain near the anchor. For greater depths ⅜-inch wire rope is used, the buoy containing sufficient barrels to suspend it (see **2833**).

For anchoring in extreme depths (500 fathoms and more) stainless steel wire rope of smaller diameter has recently been used with gratifying results. The sizes of commercially manufactured stainless steel wire rope recommended for this purpose are 3⁄16- and ¼-inch diameters in both 7 by 7 and 7 by 19 construction; the 7 by 7 is less flexible but more durable than the 7 by 19. The stainless steel wire rope is stronger and more durable than ordinary galvanized steel wire rope of comparable size, and costs approximately three times as much. The higher cost is warranted to prevent loss of buoys because of anchor cable failure, but aside from this the exclusive use of stainless steel rope may be actually more economic because of its more durable qualities and its resistance to corrosion. The life of ordinary wire rope, when constantly exposed to sea water, is seldom more than one season (6 months), but stainless steel rope will probably prove to have a usable life of several years.

Galvanized iron used in conjunction with stainless steel rope in sea water is likely to corrode seriously if immersed much longer than 1 month. Direct contact between the two, sets up an active electrolytic action which removes the zinc and corrodes the metal, the effect decreasing as the distance between the two increases. Stainless steel thimbles and shackles are available for use with stainless steel rope and annealed stainless steel wire should be used to serve all splices in such rope. Connections between stainless steel rope and galvanized chain or other fixtures should be made with stainless steel shackles and the galvanized parts protected with a coating of asphaltum paint.

A survey party in the Gulf of Mexico in 1941 successfully used ordinary iron fittings with stainless steel rope in short sections of 20 to 30 fathoms in shoal water, but when these same fittings were used with long sections of 200 fathoms or more in deep water they corroded rapidly. The reason for this is not apparent.

Experiments have been conducted recently with buoys in currents to determine the appropriate size of wire rope and chain and the reserve buoyancy required to prevent the buoy from being towed under. These experiments indicate that the horizontal force exerted by a current of 1 knot on the anchor cable of one bare 55-gallon barrel 80 percent submerged, is about 11 pounds, with the force varying directly as the square of the current in knots (i. e., a 2-knot current will exert a 45-pound horizontal force on the anchor cable). With two bare 55-gallon barrels in tandem the force on the anchor cable is about doubled. These tests proved that the types and sizes of wire rope and chain recommended above are sufficiently strong for any expectable conditions.

### *2833. Lengths of Anchor Cable*

In order that the scope of a buoy and the variation in its position be at a minimum, the total length of the anchor cable should be the minimum that will be sufficient to maintain it in position. The holding quality of the bottom is an important factor. The buoyancy of the buoy also enters into the calculation because it may be towed under in a strong current, if a minimum of cable is used and the buoyancy is insufficient. If the buoyancy is sufficient but the cable is not long enough, the buoy may drag its anchor if the horizontal strain on it is great enough.

Specific rules for lengths of cable cannot be laid down because of the wide variety of

conditions encountered, but in general the following should prove satisfactory for buoys in the open ocean, except where unusually strong currents prevail:

(1) *In depths less than 15 fathoms.*—A total length approximately three times the depth, composed as follows:

For ordinary buoys—three times the depth of ⅜-inch boat chain.

For sono-radio buoys—twice the depth plus 2 fathoms of ⅜-inch boat chain, plus the depth minus 2 fathoms of wire rope.

(2) *In depths from 15 to 50 fathoms.*—A total length that is approximately twice the depth, composed of the depth plus 5 fathoms of ⅜-inch boat chain, plus the depth minus 5 fathoms of wire rope.

(3) *In depths from 50 to 200 fathoms.*—A total length that is approximately one and one-half times the depth, composed of one-half the depth plus 10 fathoms of ⅜-inch boat chain, plus the depth minus 10 fathoms of wire rope.

(4) *In depths greater than 200 fathoms.*—A total length that is approximately the depth plus 100 fathoms, composed of 110 fathoms of ⅜-inch boat chain, plus the depth minus 10 fathoms of wire rope.

When a buoy is to be used for only a short period of time or when it is anchored in an area where exceptionally good weather conditions prevail or in protected places, shorter lengths of anchor cable may be used.

A proportionately longer anchor cable must be used in shoal water because heavy surges are likely to cause the anchor to drag, but in deep water the greater weight of the suspended cable dampens this effect. For deeper water enough chain should be used adjacent to the anchor so that the wire rope will touch neither the bottom nor the anchor at any time. Continual dragging over the bottom soon abrades the wire rope excessively and it is likely to become kinked if allowed to come in contact with and wrap around the anchor.

### *2834. Parkhurst Anchor-Detaching Apparatus*

Considerable time is required and the hoisting equipment is subjected to excessive strain in weighing buoy anchors from depths of a thousand fathoms or more. There is also the danger of parting and losing the anchor cable. It is frequently more economic to detach and leave on the bottom the inexpensive anchor to ensure the rapid and certain recovery of the more expensive stainless steel anchor cable. To effect this an anchor-detaching apparatus has been designed consisting of three parts; a cone-shaped clamp, a detaching housing, and a heavy messenger. These can be requisitioned from the Washington Office.

The brass cone-shaped clamp, 4 inches long and 2 inches in diameter, consists of two halves between which the wire rope lies in a lengthwise hole of small diameter. The halves are bolted together around the wire by four stud bolts in a recessed section of the cone. The clamp is attached, pointed end uppermost, to the lower end of the wire rope which is to be retrieved.

The detaching housing of cast brass is projectile-shaped, 11 inches long by 2¾ inches in diameter, and it too is constructed in two halves, called *fingers*. The two fingers are pinned together at the lower square end by a half-inch diameter hinge pin, which also passes through the end link of the anchor chain, which is to be left on the bottom. The interior of the upper tapered end of the housing is machined to fit the cone-shaped clamp. The fingers are held firmly together around the clamp by a fixed cross pin into a hole in which a trigger pin is inserted through a longitudinal hole in one of the fingers. The trigger pin is held in place by a lead shear pin. The trigger is formed by the lower end of the trigger pin being bent at right angles to extend well outside the housing, where it will be struck by the messenger on its downward trip as it passes over the housing.

The messenger is a 50-pound oval-shaped iron weight cast in two halves, which are hinged on one side and may be clamped together on the other side by two toggle-type trunk clasps. When clamped, it has a hole through the center about 3 inches in diameter, through which the housing can pass easily.

In use the apparatus must be attached far enough up the anchor cable so that it will not touch the bottom nor the anchor. The cone-shaped clamp is attached to the lower end of the stainless steel wire rope and the detaching housing is locked in place around it. To the lower end of the housing is attached the upper end of the anchor chain.

Before using the apparatus to detach the anchor, the anchor should be raised a few fathoms off the bottom in order to remove all slack from the anchor cable. With the anchor cable held taut, the messenger is secured about it and released. As the messenger passes over the releasing housing it strikes the trigger pin, and removes it entirely; the fingers are released and the weight of the anchor makes them spring apart and fall away from the anchor wire. Thus the releasing housing, messenger, and heavy chain and anchor are left on the bottom, while the anchor wire is hoisted aboard with only the clamp attached.

### *2835. Methods of Attaching Anchor Cable*

There are a number of general precautions to be taken when buoys are anchored in exposed areas with a single anchor cable and are thus free to swing about their anchors with changes in wind and current. Swivels are usually used as connections in the anchor cable to avoid snarls in the chain and kinks in the wire rope. A ⅝-inch galvanized drop-forged swivel or swivel shackle is satisfactory and one should be used at each end of the main anchor cable and at one end of any short section in which twists may occur, such as between the sono-radio buoy and the relieving buoy.

Screw-pin anchor shackles are used to join sections of anchor cable and elsewhere where swivels are not needed. For the more permanent connections ⅝-inch shackles are used, but a ¾-inch size is recommended for any connection which must be quickly shackled or unshackled when the buoy is being anchored or hoisted aboard, because

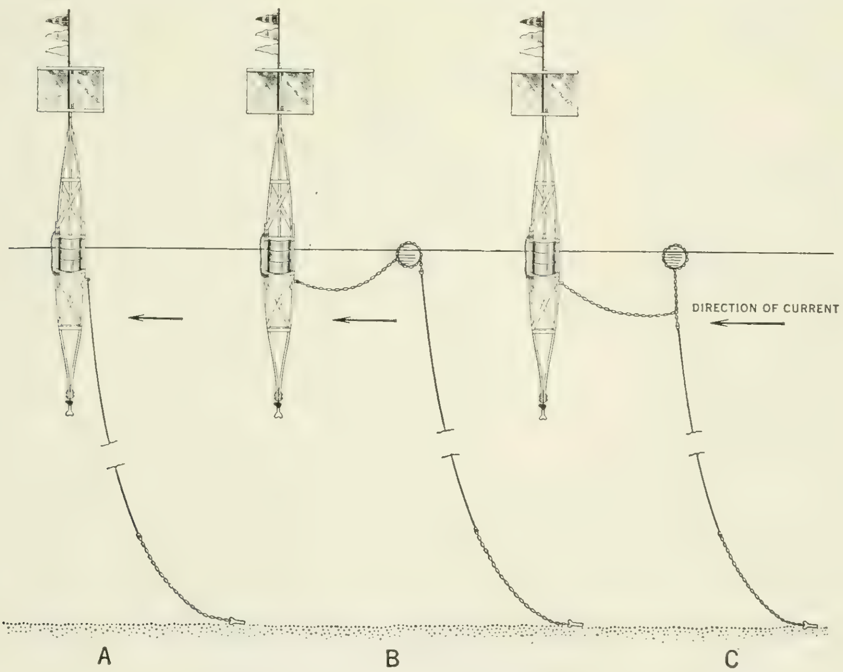


FIGURE 47.—Arrangements of buoy anchor cables.

it ise asier to engage and there is less likelihood of losing the larger screw pin. Because buoys are in continual motion, the screw pin of *every* shackle used should be secured by seizing wire through the shackle and the hole in the pin.

The anchor cables of buoys used in shoal water and at places where the currents are not strong may be attached directly to the eyebolt in the buoy structure. A ⅝-inch swivel is shackled to the chain (or wire rope) by a ⅝-inch shackle, the other end of the swivel being shackled to the eyebolt with a ¾-inch shackle. The same arrangement of a swivel and two shackles should be used to attach the cable to the anchor. A buoy anchored in this fashion is sketched in *A*, figure 47.

A sono-radio buoy is generally anchored with an intermediate buoy (relieving buoy) to support the entire weight of the anchor cable in the prevailing current. Ordinary survey buoys are frequently anchored in this fashion where strong currents are known or suspected to exist. All of the strain of the anchor cable is on the relieving buoy which allows the survey buoy to float upright so that the visibility will not be reduced. This general scheme is shown in *B*, figure 47. The relieving buoy is a 55-gallon steel barrel around each end of which ⅜-inch chain is fastened between the end and the rolling tracks, drawn tight by connecting pieces of chain. The relieving buoy is connected to the survey buoy by means of a 4-fathom length of chain using a swivel at the survey buoy and a shackle or a ⅜-inch lap link at the relieving buoy. A shackle and swivel assembly is used on each end of the main anchor cable between the relieving buoy and the anchor.

Discarded United States Navy buoyant mine casings may be obtained from junk yards in some localities, for use as relieving buoys. These casings are pressed steel spheres, 30 inches in diameter, with a swivel to which the anchor cable may be attached. To adapt them for use as relieving buoys, a U-shaped stirrup, with a 1-inch eye in the top, is welded to the side opposite the swivel. This stirrup may be made of ⅝-inch cold-rolled steel rod and made large enough (at least a 4- by 6-inch opening) so that it may be readily engaged by a hook when weighing.

The buoyancy of the unit may be increased by the arrangement shown in *C*, figure 47. A short pendant of ⅜-inch chain (about 1 or 1½ fathoms) from the relieving buoy supports a ring to which the anchor cable and the connecting chain between buoys are secured. The pendant allows the strain of the anchor cable to be carried by both buoys. The length of the pendant chain should always be somewhat shorter than the connecting chain so that the buoys will not be brought together. This arrangement should not be used on sono-radio buoys because their heavier weight leaves little reserve buoyancy available to carry the weight of the anchor cable.

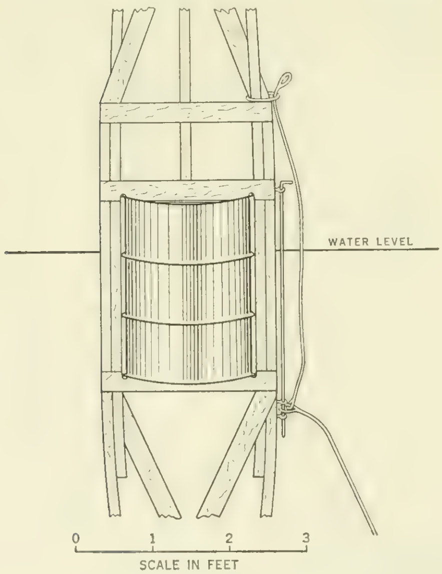

FIGURE 48.—Arrangement for a detachable buoy anchor cable.

Occasionally the anchor gear of a buoy must be hoisted on board before the buoy itself, and when this is necessary a substitute method of attaching the anchor cable to the buoy structure, as illustrated in figure 48, has been used to advantage. Three eyebolts are used in the buoy structure, one above the waterline and two spaced 2 inches apart at the position where the single eyebolt is usually placed on the one-barrel buoy (see **2824** (A)). An iron rod, bent at right angles at one end, passes through the three eyebolts and is of sufficient length so that its lower end extends a few inches below the lowest one.

The upper end of the anchor cable is made with an eye which is placed between the two lower eyebolts when the rod is inserted, thus securing the anchor cable to the buoy so that it can be easily and quickly detached. A lanyard, of the same material as the anchor cable, is spliced into the eye at the end of the anchor cable by means of an eye splice. The lanyard is long enough to extend above the waterline, and the upper end, in which there is a large eye splice, is secured to the buoy structure with a light lashing. After a hoisting line has been

secured to the upper end of the lanyard, the anchor cable may be detached from the buoy by removing the iron rod with a boat hook, the light lashing breaking easily. This allows the buoy to float free, to be picked up later, and makes it possible to hoist the anchor cable and anchor on board before the buoy structure is weighed.

### *2836. Anchoring to Reduce Scope*

If buoys are used in a large-scale survey of a shoal area, the swinging of the buoy around its anchor must be minimized in order to reduce as much as possible any uncertainty of position. This is difficult to accomplish, for it is usually inadvisable to reduce the length of the anchor cable and thus risk dragging the anchor.

The swinging radius of a buoy may be entirely eliminated by mooring with two or more anchor cables. Buoys used by the Coast and Geodetic Survey are rarely moored because the scale of the survey in which they are used is generally comparatively small and because of the additional work and material required in the duplicate anchors and cables. A satisfactory mooring with two anchor cables may be effected if the two anchors are placed in line with the direction of the prevailing current, as illustrated in *A*, figure 49. The method of mooring with two cables is described in **2851**.

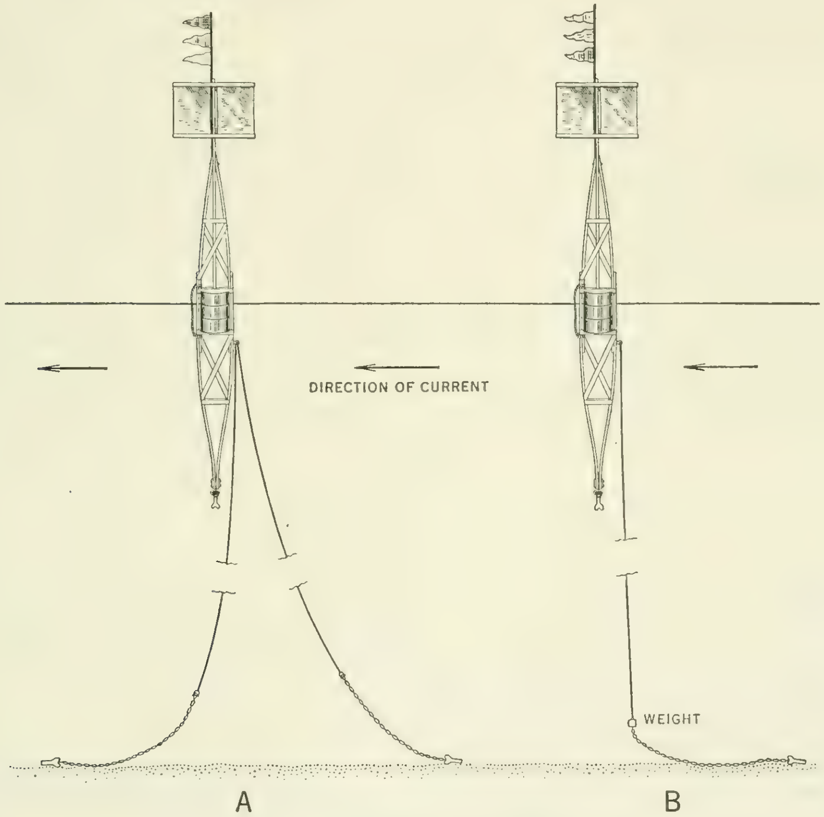


FIGURE 49.—Buoys anchored so as to reduce scope.

A simpler method of reducing scope which is satisfactory for most purposes is illustrated in *B*, figure 49. A weight (65 to 100 pounds), attached to the anchor cable about 2 or 3 fathoms above the bottom, acts as a buffer to reduce the effect of surges on the cable and permits the use of a shorter length of cable. The weight also aids in keeping the buoy structure more nearly upright and over the anchor position.

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## 284. Sono-radio Buoy

The sono-radio buoy, which is used to replace shore and ship R.A.R. stations in most of the offshore surveys, is a comparatively recent innovation.

The possibility of using a sono-radio buoy to replace a ship R. A. R. station was first proposed in 1931. Actual development was started in 1932–3, postponed, and resumed in July 1935. A sono-radio buoy was first successfully tested at sea on June 13, 1936, and they were in actual field use by the ships *Lydonia* and *Hydrographer* in July 1936. This was after the design of survey buoys had been more or less standardized, so it was natural that the first sono-radio buoy should resemble the survey buoy that had proved to be so satisfactory.

There are two types of sono-radio buoy structures: One is an adaptation of the standard one-barrel survey buoy, modified to enclose the electric equipment and to serve for the sono-radio buoy structure. It is used principally on the Atlantic and Gulf Coasts and is known as the East Coast sono-radio buoy. The other, known as the Vincent sono-radio buoy, is of all-metal construction and is adapted for use on the Pacific Coast and in Alaska. These buoy structures cannot be considered standard, as further developments and improvements are to be expected. The electric equipment for these buoys is described in section **65**.

### *2841. East Coast Sono-radio Buoy*

The sono-radio buoy that has been developed for use on the East Coast (fig. 50) is similar to the one-barrel buoy described in **2824**, but is of heavier construction to adapt it for use in any locality and to support a heavier counterweight and the suspended hydrophone. The superstructure is made slightly longer to accommodate the required length of antenna.

In localities free from strong winds and currents, a sono-radio buoy similar to the one-barrel survey buoy but somewhat lighter in construction, has been satisfactorily used. The superstructure is made of 1- by 4-inch lumber instead of 2- by 4-inch as is used in the one-barrel buoy. A special 150-pound cast-iron weight, cast to fit between the lower ends of the vertical members, is used as a counterweight.

The following specifications and list of materials are for the standard East Coast sono-radio buoy. The electric equipment is described in **652**.

#### (A) SPECIFICATIONS FOR EAST COAST SONO-RADIO BUOY

The lower parts of the vertical members are 4 by 4 inches in size, each formed of two pieces of 2- by 4-inch by 18-foot lumber, spiked together, to which the counterweight is attached. The one car coupler, with added weight, composing the counterweight is held firmly between the two vertical members by two through bolts. Wooden wedges are driven between the upper end of the car coupler and the frame at the upper bolt, to prevent any movement in the frame which might result in a sound that could be picked up by the sensitive hydrophone.

Two barrels, a large and a small one, are generally used for greater stability, but it may be constructed with the larger barrel alone, in which case the size of the counterweight must be limited to one standard car coupler of 180 or 200 pounds weight. The large barrel, made of 16-gage galvanized iron, is 40½ inches high, 22 inches in diameter, has a capacity of about 65 gallons, and contains all the radio equipment and batteries. The barrel usually used for this purpose is Wilson and Bennett Company No. 6546*G*, or equal.

The smaller barrel is made of 19-gage galvanized iron, is approximately 38 inches high and 18 inches in diameter; it contains no equipment and it is used only for additional buoyancy. Wilson and Bennett Company barrel No. 3539*G*, or equal, is satisfactory for this purpose.

The large barrel has a detachable cover, 15 inches in diameter, held in place by twelve 5/16-inch bolts and made watertight by a tubular rubber gasket that fits under the cover. In the center of the detachable cover is a 2½-inch threaded opening, fitted with a screw plug, through which the sen-

sitivity of the sound receiver may be adjusted without removing the entire cover. There are two other threaded openings in the head of the barrel, on opposite sides of the 15-inch cover, fitted with 1-inch packing glands. The hydrophone lead passes through one of these openings and the antenna lead through the other. When the sono-radio buoy is assembled the radio equipment is attached to the underside of the cover, and the batteries, packed securely in a wooden rack of circular shape, are placed in the bottom of the barrel and held in place by wooden wedges.

The large barrel is held in the frame by means of two semicircular iron straps around the barrel near its top, bolted to the frame with through bolts. Two wooden cross braces, notched to fit the chimes, are nailed to the two sides of the frame to hold the bottom of the large barrel in place. The small barrel is placed below the large barrel, the undersides of the same cross braces being notched to fit its chimes. The lower end of the small barrel is held by the tie rod which is drawn tight enough to hold it securely in the frame.

The vertical frame is extended 6 feet above the top of the barrel by two pieces of 2- by 4-inch lumber nailed on each side. To each of these is bolted a piece of 1- by 4-inch lumber to support the antenna mast. The mast may be made of either 1- by 4- or 2- by 4-inch lumber held in place between its supporting pieces by bolts. The antenna is secured to the narrow edge of the mast by means of screw-type house bracket insulators. The entire antenna assembly is bolted to the frame so that it may be detached. The rope hoisting sling and the eyebolt, to which the anchor cable is attached, are assembled as explained in **2824**(C).

A 2- by 4-inch crosspiece is nailed across the upper ends of the two 2- by 4-inch lower frame members just above the upper tie rod. This crosspiece serves to support a watertight box containing the antenna coupler, high enough so that it will not be submerged.

The hydrophone is suspended by a ⅜-inch flexible copper cable from a 2- by 4-inch crosspiece nailed on the lower frame 2 feet above the top of the counterweight. The hydrophone lead is secured to the wood frame by brass clamps (although not so shown in the figure) and extends to the hydrophone with sufficient slack so that the weight of the hydrophone is not suspended on the lead. Both the copper cable and hydrophone lead are enclosed in a section of discarded rubber hose which protects them from chafing. The hose is secured to the lower end of the counterweight.

Flags and screen-wire banners should never be used on sono-radio buoys, because if either touches the antenna, the circuit is affected. Small crossed banners made of cloth, not larger than 18 inches square, may be used. They should be nailed to the mast so they do not touch the antenna, and the cloth should be secure enough so that there is no likelihood of it tearing and being blown against the antenna. Banner masts should not be attached above the antenna masts, because the added strain may break the antenna mast.

### (B) LIST OF MATERIALS* FOR EAST COAST SONO-RADIO BUOY

| *Description* | *Size* | *Number required* |
|---|---|---|
| Lumber (see 281) | 2″ by 4″ by 18′ | 4 pieces. |
| Lumber (see 281) | 2″ by 4″ by 16′ | 2 pieces. |
| Lumber (see 281) | 1″ by 4″ by 16′ | 2 pieces. |
| Lumber (see 281) | 1″ by 4″ by 10′ | 1 piece. |
| Wedges, wooden | to fit | 2 each. |
| Barrel, G. I., with special removable head | 65 gallons, 22″ diameter | 1 each. |
| Barrel, G. I. | 30 to 35 gallons, 18″ diameter | 1 each. |
| Car coupler | Weight added to make 250 pounds | 1 each. |
| Bolts, with hexagonal nuts | ⅝″ by 16″ | 2 each. |
| Washer plates | 3″ by 5″ by ½″, drilled for ⅝″ bolt | 4 each. |
| Strap, bent to fit semicircumference of large barrel | 2″ by ¼″ by 36″ | 2 each. |
| Rod, tie, threaded both ends | ½″ by 26½″ | 1 each. |
| Rod, tie, threaded both ends | ½″ by 28″ | 1 each. |
| Bolts | ½″ by 6″ | 4 each. |
| Bolts | ½″ by 4″ | 7 each. |
| Bolts, with countersunk head | ½″ by 4″ | 4 each. |
| Nuts, hexagonal | ½″ | 19 each. |
| Washers | 1¼″ by 3⁄16″ (9⁄16″ hole) | 22 each. |
| Eyebolt, with hexagonal nut and washer | ¾″ by 6″ | 1 each. |
| Nails | 12 d. and 20 d. | |
| Rope, Manila | 4″ | 15 feet. |
| Standard enameled buoy plate | | 1 each. |

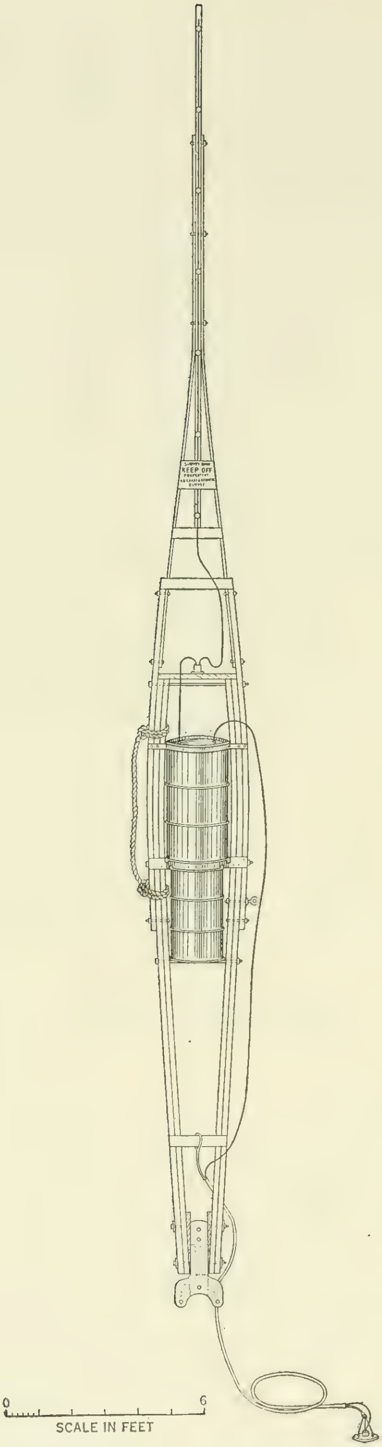


FIGURE 50.—East Coast sono-radio buoy structure.

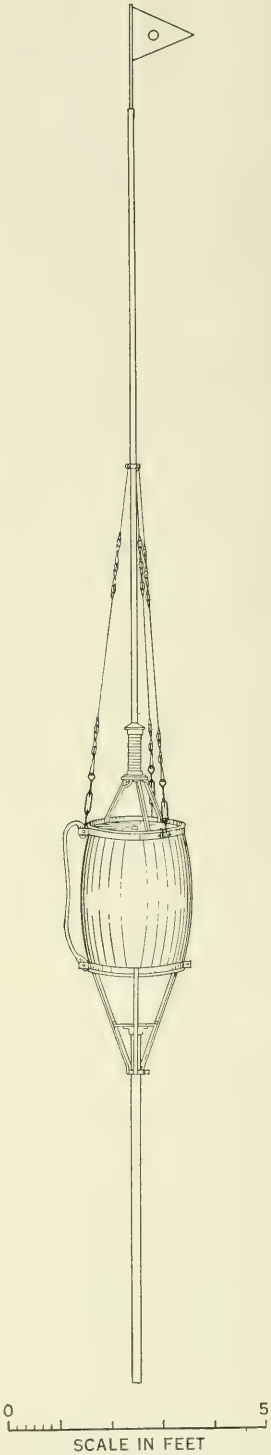


FIGURE 51.—Vincent sono-radio buoy structure.

### *2842. Vincent Sono-radio Buoy*

The Vincent sono-radio buoy (fig. 51) was designed on the Pacific Coast and it is particularly adapted for use on that coast and in Alaska where it has been used exclusively. It is of all-metal construction, comparatively light in weight, and is easy to handle in anchoring and weighing. The various parts are detachable and the buoy occupies little stowage space on board ship. The electric equipment for this buoy is described in **651**.

#### (A) SPECIFICATIONS FOR VINCENT SONO-RADIO BUOY

There are, essentially, three parts to the Vincent sono-radio buoy: A steel barrel containing the radio equipment and batteries; a superstructure that consists of an antenna, antenna support, and suitable insulating equipment; and an underwater extension incorporating a counterweight.

The barrel is of a standard 55-gallon bilge type construction. It is made of 13-gage chrome steel, hot-dipped galvanized, and it is strong enough to need no external ribs or bracing, offering minimum resistance to wind and current. The barrel has a full removable cover, whose edge is rounded to fit the rolled chimes of the barrel. The cover is held on the barrel by a semicircular split ring, fitting over the rounded edges of the cover and chimes. The cover may be removed when one bolt is loosened in the split ring, allowing it to spring apart. The barrel is made watertight by a rubber gasket fitting under the cover. The cover is made of 12-gage chrome steel and in it is a 4-inch handhole, fitted with a screw plug and gasket, and two watertight packing boxes in holes near the edge of the cover through which pass the leads to the antenna and hydrophone.

The superstructure of the buoy is supported on the barrel cover; it consists of a tripod support, an insulator which encloses the antenna coupler, the antenna which is made of one or two sections of metal tubing and a duralumin pennant, and three insulated wire guys attached to the barrel.

The tripod support consists of three pieces of 1- by ¼-inch strap iron welded to the cover, surmounted by a 6-inch diameter plate. A 3-inch pipe flange is welded to the top of the plate to hold the antenna insulator.

The main antenna insulator is a bakelite cylinder of 3¾-inch outside diameter, 2½-inch inside diameter, and 12 inches long. Both ends of this cylinder are turned down on a lathe and threaded, one end to fit in the 3-inch diameter pipe flange and the other end to take a 3-inch pipe cap. While it is in the lathe, grooves are cut in the outside surface of the bakelite to increase the leakage distance.

The antenna is usually made of one 12-foot section of 20-gage chrome-molybdenum steel tubing of 1¼-inch diameter, which is threaded into the pipe cap fitting on top of the antenna insulator. An additional 4 feet of ¾-inch diameter rod of aluminum alloy and a duralumin pennant may be used if desired. The antenna is supported by three guys whose upper ends are attached to a guy collar clamp, and which lead, through turnbuckles, to a three-segment ring, which is bolted around the barrel under the chime by means of three dogs. The guys are made of 3⁄16-inch stainless steel cable, 7 by 7 construction, and each guy includes four 2-inch porcelain insulators, two near the top and two near the bottom.

The bottom structure consists of a tripod support made of 1½- by ¼-inch strap iron welded to two semicircular pieces of metal that fit and clamp to the bottom diameter of the barrel, and welded to a collar clamp which fits a 2-inch diameter water pipe. The water pipe, used for the counterbalance, is usually 7 feet in length and is counterweighted with 25 pounds of lead that is melted and poured into its lower end. The upper end of the pipe is screwed into a 2-inch pipe flange welded to a 6-inch diameter plate on the bottom of the barrel. This plate is held in the center of the tripod by radial strips welded to each leg which serve to stiffen the structure. The pipe is then braced where it passes through the collar clamp. Screwing the pipe into the pipe flange permits the use of varying lengths of pipe to obtain a proper balance for the buoy.

The buoy is provided with a hoisting sling, made from ¾-inch galvanized steel cable, with an eye spliced in each end. The sling is attached in the bolts for the dogs at the upper and lower ring clamps, and the anchor cable is shackled to the opposite dog bolt on the lower ring clamp.

The antenna lead is carried through one of the watertight packing glands through a ½-inch welded tube to the antenna coupler in the bakelite insulator. The lead to the hydrophone is carried through the other watertight packing gland to the hydrophone which is suspended by a cable lashed to the bottom of the counterbalance pipe.

(B) LIST OF MATERIALS FOR VINCENT SONO-RADIO BUOY

| *Description* | *Size* | *Number required* |
|---|---|---|
| Barrel, bilge type, full removable head | 55 gallon | 1 each. |
| Tubing | 20 g. 1¼″ diameter | 12 feet. |
| Tubing (optional) | 26 g. ¾″ diameter | 4 feet. |
| Pennant (optional) | 26 g. 12″ by 15″ | 1 each. |
| Insulator, bakelite | 2½″ i. d. by 3¾″ o. d. by 12″ long | 1 each. |
| Pipe flange and pipe cap, cast bronze, for insulator | 3″, standard pipe thread | 1 each. |
| Guy, cable, stainless steel | 3⁄16″, 7 by 7 construction | 25 feet. |
| Insulators, guy, airplane, porcelain | 2″ | 12 each. |
| Turnbuckles, G. I. | ⅜″, 6″ opening | 3 each. |
| Guy collar clamp | 1½″ by ⅛″ | 1 set. |
| Strap iron | 1″ by ¼″ | 12 feet. |
| Strap iron | 1½″ by ¼″ | 18 feet. |
| Eyebolts | ⅜″ by 4″ | 3 each. |
| Bolts and nuts | ½″ by 3″ | 5 each. |
| Plate | ⅛″ by 6″ diameter | 2 each. |
| Pipe, water, G. I. | 2″ | 7 feet. |
| Pipe flange | for 2″ water pipe | 1 each. |
| Lead, pig, for counterweight in bottom of pipe | | 25 pounds. |
| Hoist loop, steel cable | ¾″ with two eye splices | 40 inches. |

### *2843. Streamlined Buoy*

A streamlined buoy has been designed for use as a sono-radio or radio-current buoy. Preliminary use of this buoy indicates that it may have many advantages where strong

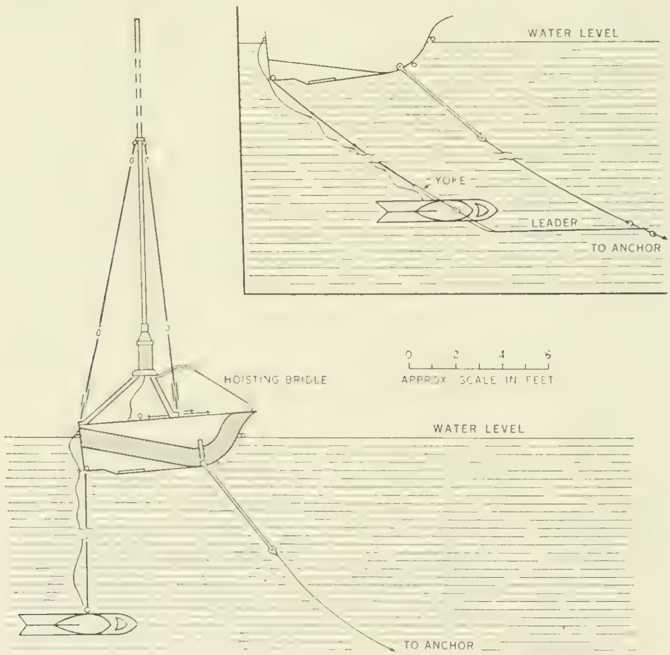


FIGURE 52.—Streamlined buoy for use in strong currents.

currents are prevalent. Figure 52 indicates its general appearance. Construction specifications and drawings are available. The buoy itself weighs 250 pounds and displaces 1,450 pounds; fully equipped as a sono-radio buoy it weighs 450 pounds.

This buoy maintains an antenna nearly vertical, well out of the water, in a comparatively rough sea and strong current, and it floats steadily without yawing. When used as a sono-radio buoy, it seems to produce no objectionable water noises to be picked up by a hydrophone. The strain on the anchor line is less than with con-

ventional barrel buoys, permitting the use of lighter anchor gear. Stainless steel wire rope, 3/16 inch in diameter, composed of 7 strands of 7 wires, has been used satisfactorily for anchor cable.

The actual buoy has been towed at 10 knots, remaining steady and seaworthy. Anchored by the swivel yoke, with no relieving buoy nor counterweight, in 62 fathoms it has streamed safely in a 4-knot current; it was anchored by a 190-pound stockless anchor and a 185-fathom anchor cable. Model tests indicate that in a 10-knot current the anchor cable must be long enough so that it will lead not more than 30° below the horizontal, and in a 6-knot current not more than 45° below the horizontal.

Cross braces are provided in the buoy to which to secure the radio equipment and batteries. The buoy must be loaded well aft, using ballast if necessray to maintain a trim about 15° down by the stern, and for deep anchorages in strong currents a sufficiently long anchor cable must be used. Unless a fixed counterweight is used, the buoy must be anchored by means of the swivel yoke, otherwise the height and weight of the antenna may capsize the buoy.

Moored by a cable leading horizontally, as to a relieving buoy, the streamlined buoy with fixed counterweight may be used safely in any current likely to be encountered.

### 285. Handling Buoys From the Ship

Buoys are anchored and weighed from the deck of a survey vessel equipped with suitable tackle, booms, and winches to handle the required weights. The essential equipment is: A strong cargo boom that may be rigged so that its end extends beyond the ship's side, a heavy-duty capstan or an anchor winch with drum (niggerhead) powerful enough to hoist the required weight, adequate tackle so arranged that the running fall will pass freely between boom and hoisting equipment, and sufficient deck space under the boom in which to rig and handle buoys. The tackle should be rigged in as simple a manner as possible and arrangement made for changing falls by the use of snatch blocks. This is of special importance in weighing buoys if only one winch is available for hoisting. If a survey ship is not equipped with a cargo boom, buoys may be handled with a boat davit amidships, although generally not with the same facility. On a single-screw vessel a davit on the port side should always be used.

Buoys are handled best from the port side of a single-screw vessel, because it generally backs to port, turning the bow away from the buoy when it is released. Buoys may be handled from either side of a twin-screw vessel, the engine opposite from the buoy being used in backing away in order to swing the bow away from the buoy. The side of the vessel from which buoys are to be handled must be free from other outboard rigging which might foul them while they are in the water alongside. The locations of the wire sounding machine and the electric submerged log must be considered. The submerged log should always be drawn inboard when weighing buoys, but this is not necessary when anchoring them provided the log is on the opposite side. Interfering awnings and wind breakers should be removed, in order that the officer on the bridge may have an unobstructed view of all operations and be able to maneuver the vessel to the best advantage at all times. The rail and side of the ship under the cargo boom should be protected from possible damage by boards or other fender material, especially when buoys are handled in rough weather.

In handling buoys, an efficient and experienced deck force is required, so that each member has his several duties to perform, and performs them rapidly and efficiently in a cooperative manner to the end that the job will be completed in the least possible time. Each member of the crew should be assigned a succession of duties;

and after each is completed, he should, on his own initiative, obtain the implement or material required next and stand by ready to perform his next duty at the required time. The officer on the bridge should watch every detail of the operation, to see that it is correctly executed, and so that he can assist by maneuvering the vessel correctly at the proper time. Shouted instructions between the bridge and the deck, which risk being misunderstood, should be unnecessary. The required maneuvers should be anticipated and the officer on the bridge should always have the ship in the proper position to facilitate the operations.

Twin-screw vessels are generally easier to maneuver into position than single-screw vessels. The heading can be more easily maintained and the direction of the heading may be changed without changing the ship's position appreciably by working the engines against each other. Maneuvers must be made with greater caution and at a slower speed with a single-screw vessel.

Regardless of the type of vessel, buoys are anchored with the wind or current acting against the side of the ship from which the buoy is to be released. The wind should preferably be about four points on the bow so that the ship will drift away from the buoy when it is placed in the water. The ship should always have a little sternway when the buoy is released; never under any circumstances, headway, if the buoys are handled from the bow. As the ship moves slowly astern the anchor cable is payed out until it is all clear, when the anchor is released. The ship should have sufficient sternway to clear the position, for the buoy is towed toward the anchor as the latter sinks to the bottom.

The maneuvers required to go alongside a buoy to weigh it or change the buoy structure are more difficult. The ship should be maneuvered to a position on the downstream or lee side of the buoy. This may be determined by the direction between the buoy and its relieving barrel or, if no relieving barrel is used, by the rope hoisting sling which is always located on the opposite side from the anchor cable. When the ship is in the appropriate position it should be headed into the current, directly for the buoy, and the speed reduced. The approach should be painfully slow in order not to overrun the buoy, but steerageway must be maintained. The approximate speed of the ship may be judged by the ripple marks, bubbles, or small pieces of floating matter on the surface of the water as they are passed. The last hundred meters should be traversed with the engines stopped, so that they may be reversed momentarily when the buoy is on the bow and the ship will be almost stationary when the buoy is directly beneath the cargo boom, and can be maintained in that position until the buoy is hooked. It should never be necessary to give the ship sternway as this is likely to turn the bow too far away from the buoy. If the buoy can be hooked quickly enough, a very little headway is advantageous to avoid putting a strain on the anchor cable, since the anchor is still ahead of the ship. This requires delicate maneuvering, and considerable experience is necessary before buoys can be regularly weighed expeditiously with a single-screw vessel without damaging them.

In general, the necessary maneuvers are more easily made in moderate currents and moderate winds, because steerageway can be maintained with little or no headway. Surprisingly enough a calm sea with no current nor wind is not a particular advantage in weighing buoys, especially with a single-screw vessel. The following are

probably the most favorable conditions in the order of preference, although there is no general agreement as to this:

(a) Moderate current, no wind, no sea.
(b) Moderate current, light breeze (in same general direction as current), no sea.
(c) No current, moderate breeze, little sea.
(d) No current, no breeze, no sea.

However, when the direction of the current is at an angle with the direction of a strong wind it is frequently difficult and at times impossible to weigh buoys. Under these conditions, the ship should be headed for the buoy in a direction to head into the stronger of the two, or on a heading midway between them. Maneuvers have to be made at a faster speed and more use is made of the engine in maintaining the course.

Where wind-induced currents prevail, for lack of better information, coastal currents may be assumed to set in a direction about 20° clockwise from that direction toward which the wind blows (in the Northern Hemisphere) and in the open ocean about 40° clockwise. For the Southern Hemisphere the differences are in a counterclockwise direction. The rule for coastal currents is not always applicable, especially when near the shore where the direction of the current depends on the angle between the wind direction and the coastline.

In strong winds and currents the deck force has to act speedily in engaging the buoy and hoisting it aboard. After the buoy is on board, the ship should be held in position over the anchor so that the anchor cable will be approximately vertical while it is being weighed. The anchor cable may lead slightly outboard or fore and aft, but it should never be allowed to lead under the ship because of the strain and danger of parting it.

It is difficult to substitute one buoy structure for another without disturbing the position of the anchor, particularly when the sea is rough or when the wind and current are in different directions. For this operation it is necessary to hold the ship in position on the required heading for the comparatively long time required to perform the necessary operations on deck, without putting any strain on the anchor cable. Only if the heading can be maintained, with the anchor cable hanging almost vertically in the water at all times, is there complete assurance that the anchor has not been dragged from its position. With a twin-screw vessel this operation is performed much more easily than with a single-screw vessel.

Buoys may be anchored during comparatively rough weather or during periods of poor visibility. Unless it is necessary that they be in alinement, they may be anchored during fog. Even during poor visibility they may be alined satisfactorily for a buoy traverse by the observation of a back bearing on each successive buoy just before it is lost to view, in order to establish the correct course to run to the next. In weighing buoys, fair visibility is required in order to find them, and the sea must not be so rough that it is impossible to come alongside them to hook them with the hoisting line.

### *2851. Anchoring Buoys*

The usual method of anchoring buoys in average depths of water for buoy traverses is to lower the buoy structure into the water first, followed by the relieving barrel, if used, with the anchor cable attached. The ship is then allowed to drift, or is backed, slowly away from the buoy as the anchor cable is payed out. The wire rope section

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of the cable must be payed out with caution to ensure that it does not kink during the maneuver. Several men assist in this operation; one man uncoils the wire rope, another straightens it, and a third, at the rail, watches to see that it is not payed out too fast. The chain, previously faked on deck, is payed out much more easily. In the meantime the anchor, held by a trip hook, has been hoisted over the side and is released when the end of the anchor cable is reached.

Where a buoy must be anchored exactly at a certain preselected position, the above method cannot be used because of the impossibility of releasing the anchor at the desired position. The procedure must be reversed and the anchor lowered first. The buoy and all of its gear are assembled on deck in readiness, the anchor with the cable attached is hoisted over the side, secured at the rail by a trip rope around the anchor cable, and the wire rope and chain are faked in loops on deck in a manner to pay out freely. When the approximate position has been reached, the buoy with anchor cable attached, is hoisted over the side and lowered to the surface of the water by a trip line and held in readiness. Upon receipt from the bridge of the signal to let go, the anchor is dropped by releasing the trip rope from the anchor cable. The ship should be given sternway and the remaining anchor cable allowed to run out. When it is all clear, the buoy is released by means of the trip line and allowed to float free. This method is generally used for only moderate depths; it is not recommended for use in deep water because of the risk of kinks in the anchor cable and possible injury to personnel as the anchor cable runs out at great speed.

In deep water, buoys are anchored either by stretching the anchor cable in fleets over the side of the ship from forward to aft or by carrying the cable out in a launch. In the first method the cable is drawn taut and secured over the side by light marline lashings at the ends of the loops and lashings of double sail twine at three intermediate points between loop ends. The upper fleet should be placed over the side low enough to be free from all obstructions on the ship's side. Each successive fleet should be about 2 inches lower than the preceding one. The anchor is attached to the end of the cable in the lowest fleet and is suspended over the side by a trip rope.

The buoy and its relieving barrel are lowered into the water and the ship is backed away while about a hundred fathoms of the upper part of the anchor cable, not included in the fleets, are payed out. When all of this anchor cable is over the side, the anchor is released by the removal of the rope stop and allowed to drop. As it sinks, its weight breaks the lashings on each successive fleet, but its descent is retarded so that the cable is payed out gradually. It may be necessary to cut the last few lashings if the anchor reaches bottom before all of the cable is payed out.

In the second method the anchor cable is towed out by a launch in a direction against the wind or current. A barrel or several spherical buoys are attached to that end of the cable and when the cable has all been payed out, the barrel is set adrift from the launch simultaneously with the release of the anchor from the ship. The barrel supporting the end of the cable is later replaced by the desired buoy structure.

Buoys are moored with two anchor cables by a combination of methods. The anchor of the first mooring cable is released and allowed to reach the bottom. The ship is allowed to drift with the current while the cable is payed out, the buoy is lowered into the water and the ship continues to drift while the second cable is payed out. When

all of the cable is out and begins to tauten, the second anchor is released and allowed to sink to the bottom. To be most effective the two anchors should be alined with the direction of the prevailing current and the buoy should therefore be anchored when the current is running strongly. If this is not practicable, the vessel may sometimes be maneuvered with difficulty in the right direction by the engines.

An anchor trip hook is almost indispensable in lowering buoys and buoy anchors over the side. By its use the buoy or anchor may be lowered to the surface of the water before release. The hook should be attached to the regular fall with a snap hook, so as to be interchangeable with a different type of hook (see **2852**), which is needed for weighing buoys. A light lanyard is attached to the trigger of the trip hook, by means of which the buoy structure, or the anchor, is released when it is flush with the surface of the water. Another valuable accessory for use in anchoring buoys is a long light-weight pole with a metal U-shaped fork on the end with which the buoy can be pushed clear from the ship's side after it is afloat. It is frequently necessary to fend off buoys; sono-radio buoys particularly should never be allowed to scrape along the ship's side because of possible damage to the antenna.

### *2852. Weighing Buoys*

In weighing a buoy the ship is brought alongside and the hook on the end of the hoisting line is engaged in the rope sling on the buoy structure and the buoy hoisted to the rail. The chain between the buoy and the relieving barrel is stopped with a tie rope at the rail and the chain unshackled from the buoy. The buoy is then hoisted aboard and placed on a two-wheeled truck; the banners, flags, and counterweight are removed and the bare structure is rolled away and stowed. Meanwhile the relieving barrel has been hooked and hoisted to the rail and the anchor cable stopped with a tie rope at the rail. The barrel is unshackled and brought aboard and stowed. A whip line is shackled to the end of the anchor cable and carried to the winch head through appropriate blocks on the cargo boom and fair-leads. The sheaves and fair-leads must be large enough to permit the shackle and eye splice or any other connecting fittings to pass through them without jamming. When all is ready the rope stop is removed and the weighing of the anchor cable is started. This consumes considerable time, depending on the length of cable and the speed of the winch, permitting the deck force to clear the deck before the anchor is awash. As the wire rope comes off the winch head, it is coiled by two members of the crew. If the wire rope is in sections, they are unshackled and the length of each is noted on it for future use. When the anchor is awash, it is hosed off if necessary, brought aboard, and stowed at a convenient place nearby.

Haste is not required in weighing buoys, unless the sea is rough and the ship is likely to drift over the anchor cable, but as in anchoring them, each member of the deck force should have his assigned duties, which should be performed smoothly and without confusion in order to expedite the operation and consume as little of the ship's time as necessary.

When buoys are weighed during rough weather or adverse conditions, it is frequently impossible to maneuver the ship right alongside them to engage the hook in the rope sling. If the buoy is not too far away from the ship it may sometimes be reached with a large hook on the end of a light pole, or a heaving line may be thrown to catch

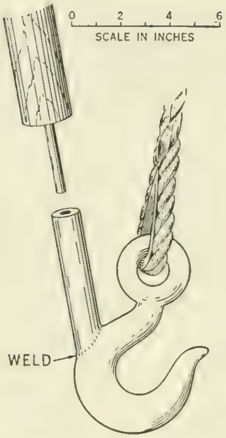


FIGURE 53.—Special hook for use in weighing buoys.

in the structure or around the buoy so that it may be drawn alongside. A light grapnel on a light line may be thrown over the chain between the buoy and the relieving barrel for the same purpose. After the buoy is brought alongside, a light line is tied around the top of the mast to guide it while it is being brought aboard.

A special hook is required on the hoisting line to engage the rope sling on the buoy structure. This type of hook is illustrated in figure 53. An ordinary cargo hook is adapted for this purpose by welding a tube to the back of the shank at the angle illustrated. The inner diameter of the tube is such that a pin in the end of a long, light-weight pole fits into it loosely. To hook a buoy, the hook on the hoisting line is fitted to the end of the pole by use of the pin and tube and held in place by a strain on the hoisting line. After the hook is engaged in the rope sling the pole is removed and the buoy hoisted.

### *2853. Record of Buoys Anchored*

Buoy station names are assigned from a prepared alphabetical list when they are anchored (see **215** and **286**). The name assigned to each is recorded on Form 714, Abstract of Buoys Planted, which contains columns for entering all pertinent data. Opposite the station name should be recorded the date when the buoy is anchored; the depth of water, reduced for tide, in which it is anchored; and its dead-reckoning position.

Under the heading "Cable" should be recorded: first, the length of chain between the buoy and relieving barrel; second, the length of chain in the main anchor cable; and last, the length of wire rope in the main anchor cable. The scope of the anchor cable may be computed and entered in meters in the column headed "Horizontal Scope" (see **943**). Under the heading "Description" a brief description of the buoy structure should be recorded. In the first column headed "Banner," the color, size, and material of the crossed banners are recorded. In the next column headed "Flag," the color of the flags and, if more than one, the order of the colors from top to bottom are recorded. Symbols and abbreviations must be used in these two narrow columns. In the last column headed "Anchor" the total weight of anchor used should be entered. Under "Remarks" space is provided for any other pertinent information, such as the character of the buoy, if it is other than an ordinary survey buoy.

The form should be used continuously during the season as buoys are anchored. It is not necessary to use a separate sheet for each date on which buoys are anchored. The separate sheets of the form are bound in a loose-leaf "Buoy Data Book" (see **94**), which is kept on the ship's bridge whenever field work is in progress.

### 286. RECORD OF BUOY POSITIONS

When many buoys are anchored and weighed at irregular intervals by different officers, it is difficult to keep track of the buoys in position at any time unless a written record is retained. A complete record of the names of the buoys and the dates on which they were anchored and removed is valuable to ensure that some buoy will not be forgotten and left at its position. The record is also used as a basis for reporting to the Washington Office the establishment and removal of buoys for publication in the weekly "Notice to Mariners." (See **8524**.)

Buoys are named from a prepared alphabetical list, the names being ruled out as they are assigned, in order that there will be no duplication during the season.

A form is ruled on heavy paper to provide a space for names assigned with three columns opposite. The first column is for the date anchored, the second the date weighed, and the third for any remarks, such as the type, use, or purpose of the buoy. This record should be kept in the front of the "Buoy Data Book" (see **94**) and shows at a glance the buoys at their stations at any time.

The officer, whose duty it is to report to the Washington Office the establishment and removal of buoys, should keep a further record by plotting the positions of the stations on a chart of the area. Different symbols are used to differentiate between types of buoys; the symbol for an ordinary buoy is a single circle and that for a sono-radio buoy is two concentric circles (see **743**). The respective station names should be noted alongside the symbols. When their establishment is reported, the positions are plotted on the chart, and when their removal is reported the circles are filled completely with ink. The plotted record has an additional value, for by it the distribution of existing control stations may be studied when extensions to the scheme are planned.

# CHAPTER 3. HYDROGRAPHY

## 31. GENERAL STATEMENT

Nautical charts which mariners use for the safe and expeditious navigation of their ships along coasts and into harbors are based chiefly on hydrographic surveys. The surveys must not only discover and locate all dangers within the area but must determine the depths of the water and where these depths are measured. For an accurate and adequate nautical chart it is necessary to collect and compile much more material than appears on the finished chart.

A complete hydrographic survey of an area may be described briefly as consisting of:

(*a*) A systematic coverage of the area with depth measurements sufficient to ensure that all dangers to navigation have been found.

(*b*) A development of all underwater features of special significance to navigators, such as channels, reefs, banks, shoals, and characteristic submarine features; and the determination of the least depths on all dangers to navigation.

(*c*) The location of the soundings, dangers, and submarine features so that they can be charted correctly with reference to the adjacent land features, or by latitude and longitude.

(*d*) Contemporary tide observations from which the soundings may be reduced to a reference plane, and often for the determination of this plane.

(*e*) Supplemental operations to locate and obtain the descriptions of numerous features, such as rocks, reefs, wrecks, aids to navigation, and landmarks, that must be charted and described in the Coast Pilots published by the Bureau (see **91**).

Sounding is perhaps the most important, as well as the most arduous, part of the hydrographer's duties. An accurate knowledge of the depths is essential to safe navigation, particularly in harbors and their approaches where the drafts of vessels are often nearly as great as the depths in which they navigate.

A topographer can examine visually the terrain and features which he is mapping; but the submarine relief is hidden from the hydrographer and its form and features can be deduced only from depth measurements systematically spaced over the area being surveyed. It is obviously impracticable to measure the depth at every point, and a hydrographic survey is considered adequate when enough depths are measured so that the slope of the bottom between them can be assumed to be uniform. Of course, there is no justification for such an assumption; however, no better method has yet been devised than to cover an area with a system of evenly spaced sounding lines. Echo sounding, particularly when recorded graphically, does provide a continuous record of the slope along each line.

The possibility of undiscovered irregularities, and even dangers to navigation, existing between sounding lines is ever present and the gravest responsibility of the hydrographer is to make sure that none remains undetected and that, when found, their least depths are determined.

### 311. Depth Measurements

#### *3111. Accuracy of Depth Measurements*

The depths of the water shall be measured with the greatest accuracy consistent with efficient progress. No depth-measuring instrument or method shall be used to sound over relatively even bottom or in critical depths which does not measure depths

less than 11 fathoms accurately within one-half foot and greater depths within 1 percent, unless specifically authorized by the Director.

In rapidly changing depths and over irregular bottom the requirements may be lowered to 1 foot for depths less than 11 fathoms, and 2 percent in greater depths. It is recognized that a depth measured in a submarine valley or on a steep submarine slope by a nondirective echo-sounding instrument may be less than the depth vertically under the survey vessel. (See **563**.) If it is important to know the vertical depths in such areas, the project instructions will specify that wire soundings supplement the echo soundings.

### *3112. Depth Units*

All depths shall be measured, and the results recorded, either in fathoms and tenths or in feet and tenths. The double unit, fathoms and feet, shall no longer be used.

Only one depth unit shall be shown on each hydrographic survey sheet—the depth unit to be used depending on the general and specific locality, the depths, and which unit is used on existing charts (see **771** to **7712**). This does not require that the depths for each hydrographic sheet be measured and recorded in only one unit, but when this is practicable the reduction of the records will be facilitated (see **8143**).

The following rules shall be followed in measuring and recording depths insofar as practicable:

(*a*) All depths of 11 fathoms or less—IN FEET (AND DECIMALS).

(*b*) Echo soundings with the Dorsey Fathometer for a hydrographic survey to be plotted in feet—IN FEET (AND DECIMALS).

(*c*) Echo soundings with the 808 Fathometer or the Hughes *MS*12*D* for a hydrographic survey to be plotted in feet—IN FEET (AND DECIMALS), except for (*d*).

(*d*) When shoal-water graphic-recording echo-sounding instruments, which can be operated to record in either feet or fathoms, are used in areas of irregular bottom, the first phase in feet shall be used to its limit (about 50 feet) but fathoms shall be used for greater depths.

The purpose of this rule is to avoid the numerous changes in phase that would be required if all depths were recorded in feet, to the extent that confusion might result and the record be unnecessarily difficult to interpret.

(*e*) All depths measured by other echo-sounding instruments, described in this Manual as used by the Coast and Geodetic Survey—IN FATHOMS (AND DECIMALS).

(*f*) Handlead soundings interspersed with echo soundings—in the same unit as the echo soundings.

Whenever a change of depth unit occurs during the day's work, the change must be emphatically indicated by writing the new unit in the "Soundings" column when the change occurs, and appropriate notation must be made in subsequent column headings (see **8143**).

### *3113. Approved Range for Methods and Instrument*

The most accurate method and instrument available, whose uses are practicable, shall be used in all depths less than 11 fathoms; but care must be taken not to extend the use of a method or instrument particularly adapted to shoal inshore areas beyond its practicable limit, where other methods or instruments are more suitable.

### *3114. Approved Methods of Depth Measurement*

No method of sounding or type of sounding apparatus, not approved by the Washington Office, shall be used in hydrographic surveying, except for experimental purposes.

The three general methods, now approved, for measuring depths are; (*a*) indirect measurement by sound (echo sounding) treated exhaustively in chapter 5, (*b*)

direct measurement by leadline or sounding pole (see **3421**, **461**, and **462**), and (*c*) direct measurement by sounding machine and wire (see **3422** and **463**). The approved types of equipment for use with each method are described under the appropriate headings. Echo-sounding instruments and sounding machines are purchased by the Washington Office and only approved types are furnished.

### *3115. Obsolete Methods of Depth Measurement*

The following methods and equipment are considered obsolete and shall no longer be used in hydrographic surveys:

*a. Pressure tubes.*—Echo sounding in recent years has rendered obsolete the use of pressure tubes for depth measurement, and their use is not approved. Various types of pressure, or sounding, tubes have been in use for many years in navigation and hydrographic surveying. The principle of the method depends on the fact that when a tube of small diameter, closed at one end, is lowered to the bottom, the water pressure forces water into the tube, compressing the air against the closed end—the amount of compression depending on the water pressure, which is a function of depth.

The type of tube formerly used in the Coast and Geodetic Survey was designed in the Bureau. The tube was made of brass and designed so as to retain the water which entered it on descent. The amount of water was measured by inserting a brass rod just far enough to bring the water level to the top of the tube. The depth was then found by comparing this length of brass rod with a suitably graduated scale.

Chemical tubes are best known in navigation. The inside of a glass tube is coated with a chemical that changes color when it comes in contact with sea water. Of course the water runs out of the tube as it is raised to the surface, but a difference in color marks the extreme point to which the water rose in the tube, so that the depth can be measured by reference to an appropriate scale. Tubes, frosted on the inside, are also used, the frosted interior appearing more opaque where dry than where wet.

*b. Trolley soundings.*—Echo sounding has also replaced trolley soundings entirely and the use of this method is not approved. This was a method of measuring depths vertically by leadline or wire, while underway, beyond the limit possible by hand leadline. The leadsman was stationed aft but the lead was dropped from a point far enough forward along the ship's side so that when it reached bottom it was vertically below the leadsman. The lead was carried forward to this point on a carriage rigged on a wire. The line was rove through a system of sheaves to the sounding machine for heaving in.

*c. Sonic Depth Finder.*—Several types of echo-sounding instruments have been used by the Coast and Geodetic Survey which are now considered obsolete for hydrographic surveying. Among these are the Sonic Depth Finder, described briefly in **5131**, and the hammer- or striker-type fathometers (see **5161D**), among which are the 412 Fathometer (see **5133**) and the 432 and the 515 Fathometers.

## 312. PROJECT LIMITS

The limits of the project will ordinarily be stated in the project instructions. When no reference is made to the offshore limits the hydrography is to be extended as far as the methods of control in use warrant, taking into consideration the desirability of surveying offshore submarine features of value to navigators using echo-sounding instruments (see **122**).

### *3121. Inshore Limits in Protected Waters*

In protected waters the hydrographic survey shall extend as close to the high-water line as practicable. The low-water line should be fully developed by the hydrographic survey in all areas where the range of tide permits. The survey should be planned so that sounding lines can be run close to the shore during periods of high tides and calm weather. This will result in a definite determination of the low-water line and in much of the area between the low- and high-water lines being surveyed.

### *3122. Inshore Limits on Open Coasts*

On open exposed coasts the hydrographic survey should extend as close to the shore as possible without jeopardy to life or property. It is always desirable to have the low-water line accurately delineated by the hydrographic survey, but on many open coasts this is manifestly impossible—for example, in regions where the range of tide is extremely small, as along the coast of the Gulf of Mexico.

Along regular sandy beaches the lines should be run parallel to the shore and advantage should be taken of periods of high tides and calm weather to run the lines nearest to shore. Under such conditions where the range of tide permits, it should be practicable to delineate the low-water line. In areas of extremely small range of tide there may be a wide band of very shoal water offshore from the low-water line which is difficult and uneconomic to develop. In such areas the inshore lines shall be run as close as practicable to the shoal area, supplemented by a few widely spaced soundings on the shoal area obtained by wading or from a pulling boat.

On rocky coasts, especially where steep-to, it is frequently impracticable to delineate the low-water line even in part and when it is dangerous to attempt this, the fact should be stated in the Sounding Record. Where it is dangerous for the sounding launch to enter a rocky area along the shore, or where kelp is so thick that the sounding boat cannot navigate through it, the fact should be stated in the Sounding Record and the area accurately outlined on the boat sheet. If the kelp area is of importance to navigation a flat-bottomed skiff should be used in calm weather to investigate the area and determine the least depth.

Where the low-water line cannot be delineated by the hydrographic survey, the areas should be fully described in the Descriptive Reports with an explanation of the conditions preventing the extension of the survey closer inshore. Copious notes should be made in the Sounding Records in such cases to show clearly that the inshore line is being run as close to the shore as safety permits, and estimated distances to the breakers or to the shore should be frequently noted in the Record. From these data the line of breakers, kelp, reefs, or other impedimenta should be sketched on the boat sheet in ink

### *3123. Navigable Streams and Estuaries*

Within the project limits all streams shall be surveyed to the head of navigation for small boats, and all tidal sloughs and estuaries to the same limit or until the low-water line has been accurately delineated, unless the project instructions specify otherwise.

## 313. PROJECT AND SURVEY JUNCTIONS

The project instructions will state specifically with what prior surveys junctions are to be made. Photographic copies of these surveys will ordinarily be furnished with the instructions (see **131**).

### *3131. Surveys of Other Organizations*

Where large-scale hydrographic surveys of other organizations exist in a project area, such surveys shall not be duplicated if they are comparable in accuracy to the surveys of this Bureau and can be utilized for charting. The United States Corps of Engineers makes periodic surveys and examinations of dredged channels, and occasional surveys of navigable streams and other inside waters. Such areas shall not be surveyed by this Bureau when a suitable agreement in depths is found at the junctions with the

most recent periodic survey. In a nonchangeable area, a contemporary survey by such an organization shall not be duplicated, if a suitable agreement in depths is reached at the junctions, irrespective of whether the survey is periodically repeated.

#### *3132. Survey Overlap at Junctions*

An overlap of at least one sounding line shall be made with an adjacent survey except as provided in **3133**, and if the depths at the junction are not in agreement, the new survey shall be extended into the old until a satisfactory agreement has been reached. If a reasonable extension into the other survey discloses no tendency toward an agreement, an investigation shall be made to determine the reason therefor and a report of the investigation and the conclusions reached made to the Washington Office with a request for further instructions. All details of such investigations should be included in the Descriptive Report.

The overlap specified herein shall apply to the following classes of surveys:

(*a*) All noncontemporary surveys.
(*b*) Contemporary surveys by a different survey party.
(*c*) Contemporary surveys of the same party made in different years; by different methods; or from different vessels, as the survey vessel and one of her launches.
(*d*) Surveys by other organizations.

#### *3133. Junctions With Contemporary Surveys*

Where the hydrographic survey is continuous in the same year, by the same method and from the same survey vessel, junctions between adjacent sheets may be made by spacing the hydrography just as it would have been spaced had the two been combined on one sheet. Any discrepancies in the depths or the depth curves at the junctions shall be investigated and corrected before leaving the field, as is required for discrepancies between any two adjacent lines of a survey.

### 314. SYSTEMS OF SOUNDING LINES

For a hydrographic survey of an area a methodical and systematic examination is the principal requirement of any system of sounding lines adopted. A system must be chosen that will develop the area and delineate the submarine relief in the most thorough and economic manner, and a series of evenly spaced sounding lines is the best method yet devised to accomplish this. The purpose of the regular systems of lines is: first, to furnish a realistic representation of the sea bottom and the submarine relief; and second, to reveal indications of shoals or dangers which are subsequently investigated for least depths.

The project instructions ordinarily specify in a general way the direction of the principal system of lines, but in parts of a project the preferred direction often depends on local conditions where the Chief of Party or the hydrographer is expected to use his judgment.

In general, a system of evenly spaced lines approximately parallel to one another and normal to the depth curves will provide the most convenient and economic development of an open coastal area, but it is frequently more advantageous to adopt some other system because of the location of the control, or the distribution of convenient anchorages or shore bases. The system adopted for the open coast is not necessarily also suitable for bays and harbors. For the development of steep features, however,

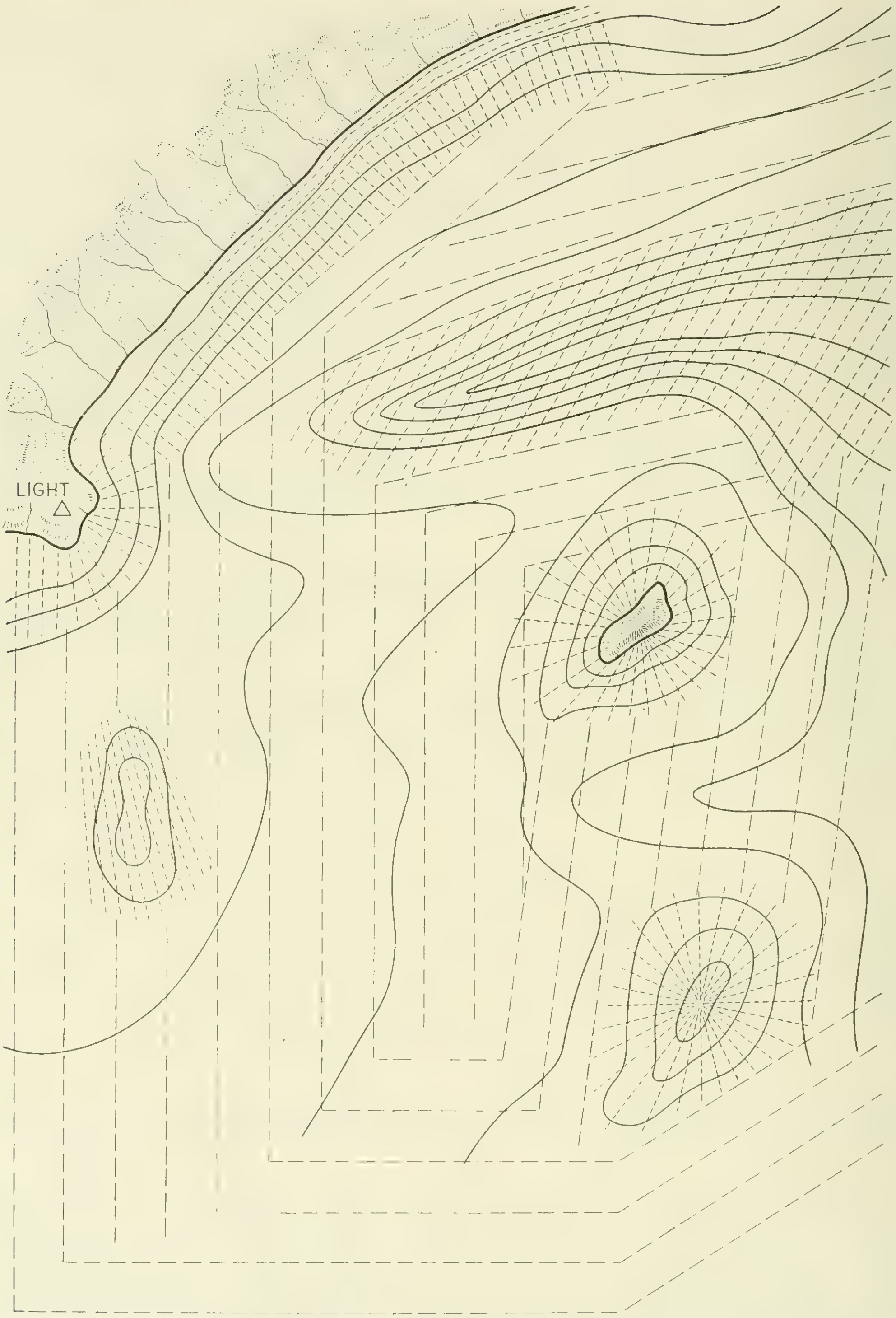


FIGURE 54.—Systems of sounding lines. The solid lines represent depth curves, and the broken lines represent appropriate systems of sounding lines for the various conditions encountered.

such as ridges or submarine valleys, the system of lines adopted should cross the depth curves at an angle of about 45°.

The selection of the most appropriate system of lines for any given area requires an understanding of the principles involved, which are discussed in **3141** to **3143** inclusive. Three systems of sounding lines are in general use: (*a*) Parallel straight lines, (*b*) radiating lines, and (*c*) circular arcs.

### *3141. Systems of Parallel Lines*

A system of evenly spaced parallel lines approximately normal to the depth curves is most frequently used, especially near the open coast. Since the inshore depth curves generally tend to parallel the coast, such a system of lines will also be normal to the coastline. The principal advantages of such a system are that the best delineation of the depth curves is obtained with a minimum of sounding; the three-point fixes are more easily obtained since fewer changes in objects are required; positions close inshore, which cannot be fixed by sextant angles, can be reasonably well determined by course and distance from the more strongly fixed positions farther offshore; such lines can be extended into small bights and indentations in the shoreline and be reasonably well controlled with a minimum of control stations; and ranges and leading marks on shore can be utilized to advantage in running the proposed lines.

The principal disadvantages of such a system are encountered in the area immediately adjacent to the shore. It is difficult to extend such lines close enough to the shore, and dangerous when heading inshore. Variations in speed when coming to a stop or when starting a line frequently result in the displacement of some of the soundings and, in turn, the depth curves. Such a system cannot be spaced adequately in proportion to the depths, except by running numerous short *splits*, since it is obvious that two parallel sounding lines run normal to the depth curves will be spaced correctly for the depth at one place but will be too close together or too far apart elsewhere. Also the prevailing winds and currents in many regions tend to parallel the coast and would be normal to the vessel's course, thus adding to the difficulty of running the proposed lines.

To avoid many of the above difficulties a system of lines parallel to the shore can be adopted for the survey of the adjacent waters, especially where the coastline has a regular trend and an even, gradually sloping bottom. Such lines can be run closer to shore since the sounding boat is running parallel to the danger line, instead of toward or away from it. Longer lines can also be run, thus avoiding the numerous ends of lines necessary in a system normal to the shoreline, and economy in operation can often be attained by starting and ending the lines nearer to the anchorage or shore base. Intervals between positions can be varied to take advantage of the locations of the control stations to obtain strong three-point fixes. The lines closest to shore can be run during abnormally high tides and a calm sea.

A system of lines parallel to the coast is impracticable where the coastline has many indentations or the shoreline is very irregular. Unless the control stations are some distance inshore from the high-water line, the three-point fixes on the most inshore lines are likely to be weak since one angle is generally extremely large and the other very small and they change very rapidly. If the control stations cannot be located some distance inshore the number required to control the inshore lines is excessive.

A system of parallel lines, whose direction is at 45° to the depth curves, is of advantage in certain areas. For the same spacing between lines, such a system provides a better development of long, narrow, steep-sided ledges or troughs. It is to be noted in this connection that the axes of off-lying shoals of this nature are frequently approximately parallel to the trend of the coast. Likewise, off-lying sand and mud banks of ridge form usually have their longer axes parallel to the coastline or parallel to the prevailing coastal currents.

In most modern hydrography, the depths are measured by echo sounding from a survey vessel traveling at standard speed so that accurate compass courses can be steered. Under such conditions systems of parallel lines are usually most convenient, for approximately the same course will serve to follow alternate lines of the system. For inshore hydrography, especially if by handlead, the sounding vessel is limited to a slower speed, making the use of shore objects to control the position of the vessel on line frequently advantageous or necessary. There are two general ways by which this is done—(1) by the use of ranges and (2) by the use of distance angles (see **3143**).

Ranges can be used to keep the sounding vessel on each of a system of parallel lines, but to do this both the front and the rear range marks have to be changed for each line. Coxswains with considerable experience in this type of work can be trained to select objects for this purpose. The selection is facilitated by using a sextant to pick up a front range mark toward which the sounding line leads. Immediately after the sounding vessel has been placed on the outer end of the sounding line, and the position fixed, the angle between the direction of the proposed line and a prominent control station is scaled from the boat sheet, and with this angle set on the sextant, a front range mark can be sought at the correct point on shore, the corresponding rear range mark being farther inshore. (See **3453.**)

For a close systematic development of comparatively large offshore shoal areas a rear range mark can often be selected far enough inshore so that for all practical purposes the sounding lines across the shoal are parallel to one another.

### A. ON OPEN COASTS

For surveys along open coasts with gently sloping bottom, the principal system of sounding lines should be either normal to or parallel to the general trend of the coast, or a combination of the two directions may be used. The directions of the lines should be chosen to give a complete and economic survey. Where the shore is a fairly straight beach, the launch survey should generally consist of at least a few lines run close in and parallel to the shore. At least enough parallel lines should be run to provide a sounded zone for the launch to turn in when running the lines normal to the shore. The area farther offshore where the slope of the bottom is gentle, may be surveyed by a system of lines run in the most convenient and economic direction.

Where the slope of the bottom is irregular or steep, and in areas where pinnacle rocks and steeply rising shoals or ridges may be expected, a system of lines normal to the depth curves should be run. Where the submarine relief is in the form of a series of narrow steep-sided ridges, or is indented by steep narrow troughs, the direction of the system of lines must be such that the lines will cross these features at an angle. If the axes of the features are parallel to the surrounding depth curves, a system of lines normal to the depth curves will provide an adequate survey. But if the axes of the features are perpendicular to the surrounding depth curves, as is the case with many of the submarine valleys and canyons along the continental slope, a system of lines

whose direction is approximately 45° to both the depth curves and the axes should be selected.

On the continental slope itself, where the gradient is comparatively steep, a system of lines perpendicular to the depth curves gives the best and most economic development.

An extensive shoal area with no pronounced axis may be adequately surveyed by a system of parallel lines run in any convenient direction. If it has a definite axis, the best development will be obtained by a system of lines run at an angle of 45° to the axis, supplemented by several closely spaced lines along the axis. A shoal of circular shape whose least depth may be expected near the center is best developed by a system of radiating lines converging near the shoalest spot (see **3142**).

### B. IN PROTECTED WATERS

In protected waters of large area, the same general considerations apply; in general a system of lines approximately normal to the depth curves will provide the most adequate development. A few lines close inshore should always be run parallel to the shoreline except where it is so indented that this is impracticable. The lines should be run during periods of high tide and in calm weather.

In small bays, harbors, and similar indentations of the coast, the directions of the lines will depend almost entirely on the configuration of the feature. They should be laid out so as to give a complete and economic development.

Extensive flats which bare at low water generally do not require closely spaced lines. A few widely spaced lines should be run over such areas to define the limits of any navigable channels therein which need to be more thoroughly sounded, and the low-water line should be located by a zigzag line of soundings run at high tide. The outer edge of the flat should be located by a system of parallel lines which will determine the line of demarcation between shoal and deep water.

Tests have proved conclusively that vertical handlead soundings cannot be obtained in strong currents, except when proceeding in the direction of the current. When channels or streams are sounded with the handlead, the entire development must consist of a series of lines parallel to the axis, the lines being run at slow speed in the direction of the current (see **3464**).

Echo soundings are not affected by the current, and when they are used, a channel or river should be sounded first by a system of lines running across the axis of the channel, either normal to or diagonal to it. Diagonal lines should be used in narrow channels and where the slope is abrupt at the edge of the channel. The lines should be run at such an angle that the change in depth will be gradual enough to permit taking a sufficient number of soundings to locate the edges of the channel and the desired depth curves. All variations in sounding speed must be noted in the Sounding Record with a sufficient number of positions taken so that there will be no doubt as to the correct positions of the depth curves. The system of crosslines will serve to locate the channel which must then be thoroughly developed by a system of lines parallel with its axis.

### *3142. Systems of Radiating Lines*

Off points where there is a marked change in the trend of the shoreline, in small bays, and around off-lying islets, radiating lines generally provide the most adequate development. It is to be noted that such lines can frequently be run around points by using a rear range mark selected so that the convergence of the lines near the shore provides the most suitable spacing proportional to the changing depths.

The development of an isolated shoal is frequently best accomplished by running a series of lines radiating from a buoy anchored near the center of the shoal. Where the coast forms a background to the buoy used as a front range mark, part of the radiating lines can be run on ranges, the remaining being run by compass course. (See also **3453.**)

### *3143. Systems of Circular Arcs*

The development of an isolated shoal area can be very effectively controlled by the use of distance angles. Two control stations should be selected, so located that the loci of the angles between them cross the shoal area in flat arcs. Preparatory to the survey a series of such loci can be drawn on the boat sheet spaced as desired (see **37**). At one end of each arc the value of the angle between the two stations is noted. With this angle set on a sextant the sounding vessel may be readily maneuvered onto the line and maintained there by periodic observation of the angle, the course being changed slightly to maintain the angle *on*. Distance angles are particularly advantageous when the sounding vessel must proceed at slow speed and either the wind or current is strong and variable. Only by the use of this method, or ranges, can a system of closely spaced lines be run without having the sounding vessel get too far off line. Where the principal system of lines has been controlled by distance angles, any required *split* line can be accurately run by using the mean of the two distance angles used for the lines on each side of the split.

## 315. Spacing Sounding Lines

The proper spacing of sounding lines depends on the scale of the survey, the depth of the water, the proximity to shore, the character of the submarine relief, and the importance of the region. The general spacing should give a methodical representation of the depths and generalized depth curves in the area, and be sufficiently close to give indications, at least, of all banks and dangers therein. Subsequent *splitting* of the general system of lines and additional development must be adequate to locate all dangers and shoals, to determine the least depths on them, and to enable the hydrographer to draw all depth curves with assurance.

The maximum spacing of lines for the various zones or depths of the project is ordinarily prescribed in the project instructions. It is to be noted that this is the maximum spacing, and it is the responsibility of the Chief of Party to reduce this spacing as necessary to obtain an adequate development in any specific part of the project area. If the Chief of Party is of the opinion that the general spacing specified in the project instructions should be changed for the entire area or for large parts of it, he shall make suitable recommendation to the Washington Office and ask for additional instructions.

It is obvious that, although sounding lines can be run with refined methods at as close intervals as desired, there is a practicable limit to the number which can be plotted at any given scale. In general, four or five sounding lines to an inch on the sheet can be plotted and the soundings inked without difficulty, and in small areas at least twice as many to an inch can be shown legibly if sufficient care and patience are exercised in the inking. The scales of the surveys should be selected with this in mind so that the closest spacing of lines expected to be required in an area can be conveniently shown at the scale chosen. Table 6 gives the distances between lines (in meters) which should ordinarily be allowed for various scales, and the minimum distances between lines which can sometimes be tolerated for the same scales.

TABLE 6.—*Spacing of sounding lines*

| Scale | Ordinary spacing (4 to 5 lines to the inch) | Closest spacing (8 to 10 lines to the inch) |
|---|---|---|
| | *Meters* | *Meters* |
| 1:10,000 | 50 to 60 | 25 to 30. |
| 1:20,000 | 100 to 125 | 50 to 60. |
| 1:40,000 | 200 to 250 | 100 to 125. |
| 1:80,000 | 400 to 500 | 200 to 250. |
| 1:120,000 | 600 to 750 | 300 to 375. |

### *3151. Maximum Spacing for Various Coastal Areas*

Because of the widely different conditions encountered in different areas, it is manifestly impossible to prescribe precise rules for the spacing of lines which will apply in all cases, but a general understanding of the requirements may be gained from examining figure 55 and from the discussions herein. It must be emphasized that the graphs are not intended as requirements but represent the *maximum* spacing to be tolerated in any given area at any given depth. It will frequently be necessary to decrease this maximum spacing considerably even within the regions specifically mentioned as typical for each graph.

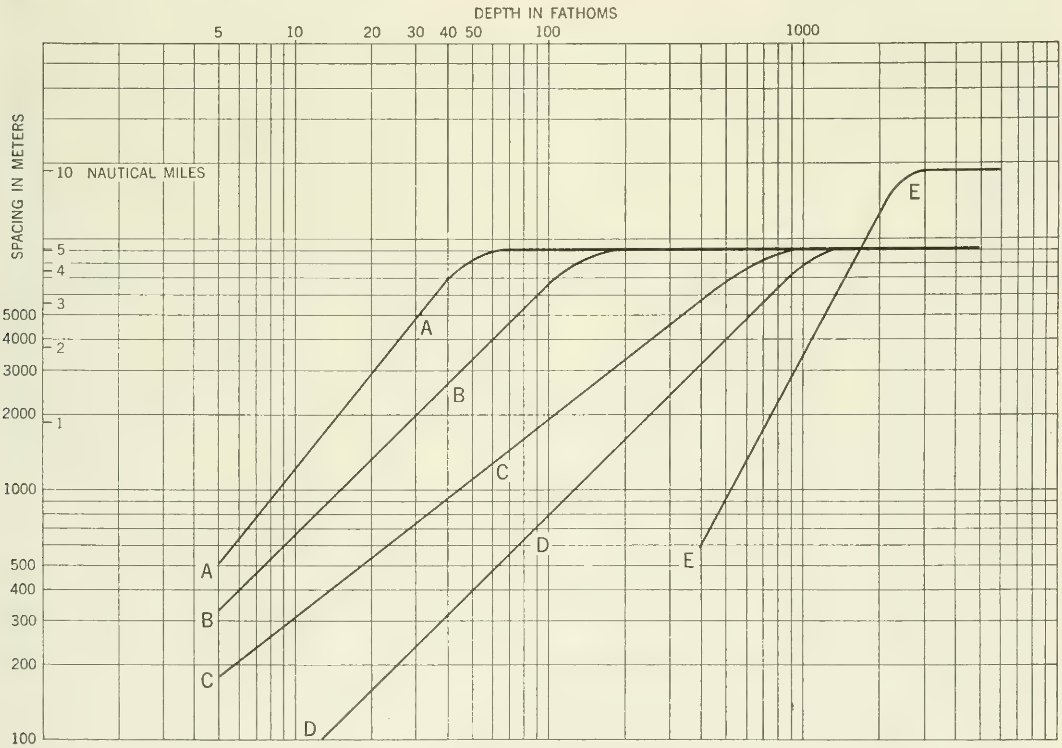


FIGURE 55.—Maximum sounding-line spacing. (See text.)
*AA* Flat sand or mud bottom without rocks, banks, or shoals.
*BB* Sand bottom with banks, but without rocks.
*CC* Areas with occasional rocky formations.
*DD* Areas with frequent steep rocky shoals and dangers.
*EE* Searches for shoals or dangers in oceanic areas.

*Graph AA* in figure 55 is applicable to coastal areas of monotonously flat sand or mud bottom, where rocks are unknown and sand banks and shoals are not to be expected, such as the Gulf Coast of the United States.

*Graph BB* should be used for coastal areas where the bottom is predominantly sand, and rocky formations are unknown but banks may be found, such as the East Coast of the United States south of New York.

*Graph CC* is applicable to areas where dangers and rocky formations are likely to exist, such as off the West Coast of the United States and Alaska.

*Graph DD* should be used in areas where there are frequent dangers to navigation and steep rocky formations rising from the bottom, or where these may be expected from a study of the adjacent terrain, such as in the waters off the coast of Maine, and in some of the inland waters of Alaska.

It will be noted that all of the above-mentioned graphs coincide at a spacing of 5 miles, which is the maximum to be tolerated for the deeper depths of any survey which is part of a project along a coast.

In a search for an oceanic danger or a steep submarine mountain rising from oceanic depths, the lines must be at closer intervals in the shoaler depths, but may be at intervals of as much as 10 miles in depths of 3,000 fathoms. For any depth, the maximum required spacing is given by *graph EE.*

Since the most economic survey of a coastal area is usually by a system of parallel lines normal to the depth curves, it is obvious that a spacing which is adequate at the inshore ends of the lines will be closer than required by the same formula for the offshore ends of the lines. To attain economy in surveying where such a system of lines is used, the interval between lines must be changed correspondingly with the changes in depth. The most satisfactory method of doing this economically is to fix the intervals between lines at multiples of one another.

If an area is to be surveyed on one sheet from one sounding vessel, in most cases it will be more economic to run the most widely spaced lines first, successively splitting the lines until the required spacing is attained. For example, suppose the project instructions specify the following spacing—200 meters at 5 fathoms, 400 meters at 12 fathoms, and 800 meters at 30 fathoms. (It is to be noted that these are the maximum allowable spacings at the respective depths, and that a proportional spacing is required at other depths—for example, at 21 fathoms the spacing should be not more than 600 meters.) To meet the requirements most economically with a system of parallel lines normal to the depth curves, lines 800 meters apart should be run first, from the shore to the offshore limits of the project. These should then be split from the shore to depths of 30 fathoms (necessary because the allowable spacing of 800 fathoms only begins in depths of 30 fathoms), and then split again from the shore to depths of 12 fathoms, using as a guide the depths obtained on lines already run. By this method, the positions of the depth curves will be known approximately from the 800-meter system and the hydrographer will know just how far offshore to run the splits. If the reverse procedure is followed, the inshore lines will almost invariably be run too far offshore in order to ensure that the required depth curve has been reached and that there is no shoaling outside of this which requires the closer spacing. Furthermore, the hydrographer runs the risk of having to run additional splits if an area of shoaler water is subsequently disclosed offshore from the outer ends of the closely spaced inshore lines.

### *3152. Sounding-Line Spacing for Inside Waters*

The general spacing for inside waters is 100 meters in bays, passages, channels, rivers, etc. This spacing may be increased to 200 meters in areas of considerable extent where uniform bottom without dangers is anticipated.

In important harbors, anchorages, channels, and areas of irregular submarine relief, lines should generally be spaced 50 meters apart, and even closer spacing may be required for complete development in certain areas.

### *3153. Lines Parallel to the Shore*

In general, hydrographic surveys should be extended inshore across the low-water line in areas where this is practicable and can be done without danger to the personnel or equipment (see **3122** and **3532**). These inshore lines should generally be run parallel to the shoreline. The spacing of a system of lines paralleling the shore shall increase gradually from a minimum next to the shore to a maximum between the two outermost lines. The two inshore lines shall be not more than 50 meters apart and the spacing between the two outermost lines should be that required for the depths found. Depending on the depths and the number of lines to be run parallel to the shore, a spacing increased 50 to 100 percent for each line should give an adequate development. For example, a 50-percent increase would give successive lines spaced 50, 75, 110, 165, 250, and 375 meters apart.

### *3154. Shoal Indications*

The spacing adopted for the regular system of sounding lines should be such that the depths obtained will almost always give an indication, at least, of every existing danger or shoal. It should not be assumed that the least depths will be obtained on the regular system of lines. Every sounding of a depth slightly less than the surrounding average depth should be regarded as a definite indication of a possible shoal; this evidence is greatly increased where shoaler soundings occur on adjacent lines in the same locality. These indications must be adequately developed by more intensive measures. (See **355** and **36**.)

## 32. THE BOAT SHEET

### 321. DEFINITION AND PURPOSE

The boat sheet is the work sheet used by the hydrographer in the field for plotting the details of a hydrographic survey as it progresses. Its use enables the hydrographer to cover an area with lines of soundings in a systematic and economic manner, to judge the adequacy of the survey, and to ascertain where additional development or investigation is required. The boat sheet is similar to the smooth sheet (see chapter 7) but necessarily less accurate because of the haste with which the hydrographer must plot each position during survey operations, because of the lack of adequate tidal data for reducing the soundings, and because of the exposure to the weather to which the sheet is subjected.

On the boat sheet the hydrographer plots the successive positions of the sounding vessel as they are observed and is thus able to determine whether the area is being systematically and adequately covered. The soundings corrected to approximate sounding datum by the use of predicted tides are also inked on the boat sheet daily during the progress of the field work. They disclose to the hydrographer uneven bottom which may require additional development to determine the least depths on rocks or shoals, and they indicate areas where additional sounding lines must be run so that the depth curves can be drawn with certainty. The boat sheet serves also as a guide to the cartographer during the plotting and verification of the smooth sheet and aids in clarifying uncertainties which may arise at such times.

### *3211. Use of Boat Sheet in Smooth Plotting*

After the completion of the field survey a boat sheet has a use which should be kept in mind by the hydrographer during the progress of the work. It serves as a guide and reference record during the plotting of the smooth sheet and its data should therefore be free of ambiguity. When plotting the smooth sheet, weight is given to the fact that the hydrographer was present at the time the survey was being made, knew the vessel's position and, regardless of the recorded data in the Sounding Record, plotted the positions on the boat sheet and connected them in accordance with the known facts, even though lack of time may have prevented extreme accuracy. (See **767**.)

### *3212. Use of Boat Sheet at the Washington Office*

The boat sheet is referred to constantly during verification of the smooth sheet at the Washington Office. If often contains supplemental details and notes which aid in interpreting the Sounding Records, including some which should be transferred to the smooth sheet. Occasionally the boat sheet is the sole source of or authority for the positions of rocks, limits of breakers, areas of kelp, etc. Such information should, however, be used with discretion, especially if it is not inked on the boat sheet. It is incumbent on the verifier to see that all data of permanent value are already on or are transferred to the smooth sheet.

The boat sheet shall be available to the reviewer and for any other purpose in connection with the survey, until after the review has received final approval by the administrative officers of the Bureau.

### *3213. Boat-Sheet Numbers*

A field number shall be assigned to each boat sheet in accordance with **1541**. The survey and all the records pertaining to it shall be identified by this number in all correspondence, records, and reports until the registry number is assigned (see **1542**), after which the latter shall be used in lieu of the field number.

Where the limits of a boat sheet are not identical with the corresponding smooth sheet, the smooth-sheet number is the controlling factor in numbering the boat sheet. If several boat sheets are used for a survey, which is all included on one smooth sheet, the several boat sheets shall bear the same survey number followed by identifying numbers in parentheses, as H–5281 (1), H–5281 (2), etc.

If, for any reason, the field survey for which one boat sheet was used has to be plotted on two smooth sheets, the numbers of both smooth sheets shall be shown on the boat sheet and on the Sounding Records involved.

Before a boat sheet is transmitted to the Washington Office, both its registry number and its field number shall be shown in one or more places on its reverse side.

## 322. Construction of Boat Sheet

A boat sheet is ordinarily constructed in the same manner as the smooth sheet (see **73** to **75**) and with limits in approximate agreement with the latter. A layout of the projection with distances noted thereon (see **7324**) may be used in constructing the boat sheet and saved for use again when the smooth sheet is made, if the projections are to be identical.

### *3221. Boat-Sheet Paper*

A good quality of cloth-backed paper obtained from the Washington Office should be used for boat sheets. Where the sheet is to be used in bright sunshine, a buff-

colored paper has been found most satisfactory to reduce the glare of the reflected light. A 100-percent rag paper, of comparatively smooth surface and heavy weight, mounted on the best grade of cotton sheeting is required. Boat-sheet paper is purchased by the Federal Government in accordance with standard specifications. The makes of paper complying with these specifications are subject to change from year to year. The General Schedule of Supplies should be consulted for the make of paper available at any given time.

When accuracy of plotting is an important factor, as in Radio Acoustic Ranging (R.A.R.), the paper recommended for smooth sheets should be used for boat sheets (see **711**).

### *3222. Boat-Sheet Limits*

The limits of a boat sheet will ordinarily be the same as the corresponding smooth sheet, except that a wider margin of spare paper is usually allowed for unforeseen contingencies and because the edges are likely to become cracked and worn in use. Occasionally after the survey has been completed, it will be found that the smooth sheet can be laid out more economically by not adhering exactly to the limits of the boat sheet.

The boat sheet need not necessarily contain within its limits the entire area to be covered by a smooth sheet. For convenience, the area may be divided and included on two or more different boat sheets, each of which shall bear the same survey number as the smooth sheet. Even if the entire area is included on one boat sheet, copies of it may be utilized if two or more hydrographic units are to survey simultaneously in the area, and all copies should bear the same survey number as the smooth sheet. (See **3213.**)

A boat sheet shall not be laid out purposely to include an area, the survey of which will subsequently be plotted on two smooth sheets.

### *3223. Accuracy of Construction*

The accuracy to be used in the construction of a boat sheet depends somewhat on the scale and the strength of positions to be expected in the area, and on the exposure to which the boat sheet will be subjected during use. For boat sheets used in R.A.R. surveys, the best quality of paper should be used and the accuracy of construction and subsequent care should be comparable to those required for smooth sheets. Accuracy of construction and care during use are important since all the distance circles cannot be drawn at the time of construction, as on the smooth sheet (see **734**). By contrast, a large-scale boat sheet for an inshore hydrographic survey, where the control stations are always comparatively near, may be constructed with less accuracy, especially since it is likely to get wet from spray in rough weather and be subjected to other hard usage during the progress of the survey.

### *3224. Methods of Construction*

The boat sheet may be constructed by methods similar to those used in constructing a smooth sheet, and if this is done the same general care and accuracy shall be used in its construction (see **73** and **74**). If there is a corresponding topographic survey on the same scale, it may be used for transferring by tracing paper (see **7561**) the projection, control, and all necessary details to the boat sheet. The projection intersections and control points should be pricked on the tracing with a fine needle point and transferred to the boat sheet in a similar manner. It is well to preserve these tracings, if they are carefully made, for possible use in making the smooth hydrographic sheets.

If the limits of the hydrographic survey extend beyond those of the topographic survey, the transferred portion of the projection may be extended to the limits of the boat sheet.

In the rare case when a smooth sheet is prepared first, a boat sheet may be constructed by superimposing the smooth sheet on the boat sheet and pricking the projection intersections and control points through with a fine needle, other details being transferred by tracing. This same method may be used with a topographic survey which is not on an aluminum-mounted sheet (see **233**).

The accuracy of construction obtained by the use of the projection ruling machine (**7327**) is not warranted in a boat sheet, and requests should not be made to the Washington Office for their construction.

When the area to be sounded has been preceded by an air photographic survey, boat sheets will sometimes be printed or prepared in the Washington Office by one of the methods described in **733**.

## 323. Preparation of Boat Sheet

A hydrographic survey can be made with a boat sheet on which appear only the positions and names of the control stations, but for an efficient and complete survey, the details described in **3231** to **3237** should be placed on the boat sheet for each area before the survey of that part is started.

### *3231. Control Stations*

All control stations, whose positions are known at the start of the survey, should be plotted on or transferred to the boat sheet.

Names of control stations may be lettered on the boat sheet in freehand, provided they are unmistakably legible. Existing names of control stations, such as triangulation stations, marked topographic stations, and previously named topographic or hydrographic stations, must be retained with their exact spelling and should be lettered when the control is plotted. New station names are to be assigned by the hydrographer in accordance with **215**. They may be assigned to all the unnamed stations and lettered on the boat sheet when the control is plotted, or during the progress of the survey as each station is used.

Where the control stations are numerous, as on an inshore hydrographic sheet, identification will be aided and confusion avoided if descriptions of those having a characteristic appearance, either in form or color, are written on the boat sheet.

For each control station in the water area, notation should be made on the boat sheet as to whether the feature on which it is erected is permanent or temporary, and a short description of the feature should be added; for example, that it is a pile, a rock, a shoal spot, a menace to navigation, or a signal erected temporarily by the hydrographic party.

Each control station that is a natural object shall likewise be briefly described. If conspicuous enough for use as a landmark, that fact shall be included in the description.

### *3232. Topographic Details*

A boat sheet for an inshore hydrographic survey should contain the high-water line, the low-water line, the approximate limits of shoal areas, rocks (bare, awash, and sunken), aids to navigation, and any suspected dangers which the topographer may have noted but may not have been able to verify or locate. The scale of an inshore hydrographic survey is almost invariably the same as that of the corresponding topo-

graphic survey. Where this is not the case, the shoreline may be omitted if its transfer presents difficulties (see **751**). In such case, however, the Descriptive Report shall include a statement that the usual verification of the shoreline and topographic details was omitted, and the reason therefor.

On hydrographic surveys which do not extend close to shore, the shoreline may be omitted entirely, or it may be generalized on the boat sheet if its representation is considered desirable by the hydrographer.

### *3233. Soundings at Junctions*

To ensure satisfactory junctions in coverage and depths with adjacent surveys, the soundings at the limits of the latter shall be transferred to the boat sheet before starting a hydrographic survey. These soundings shall appear in colored ink, preferably red, to distinguish them from soundings taken during the survey. Soundings thus transferred may be from prior surveys with which a satisfactory junction is to be made as specified by the project instructions, or they may be from hydrographic surveys currently made, either at the same or different scales.

### *3234. Data From Prior Surveys*

All dangers to navigation, including the least depths on all shoals, shall be transferred to the boat sheet from photographic copies of prior surveys in the area, if available. If such copies are not available, these data shall be transferred from the largest-scale chart of the area. In addition to least depths and other dangers, it is desirable to transfer representative soundings and depth curves from the prior surveys. All data transferred from prior surveys shall be in a distinctive color, preferably red.

It is required that the dangers, shoals, and least depths on them be definitely proved or disproved during the new survey. Comparison with the other transferred data provides a check as the survey progresses. The depth curves are especially helpful, as they enable the hydrographer to warn the leadsman or the fathometer attendant of expected changes in depth.

### *3235. Data From Published Charts*

After the data mentioned in **3234** have been transferred to the boat sheet, it must be compared with a new print of the largest-scale chart of the area, and any additional dangers on the latter transferred to the boat sheet. The printed chart frequently contains later data or data derived from other sources.

### *3236. Reported Shoals and Dangers*

In addition to known shoals and dangers, the positions of any reported menaces to navigation, which have not been charted, shall be plotted on the boat sheet, with suitable notes, so that their positions may be accurately determined or their existence disproved. Some of these reported dangers may be specifically mentioned in the project instructions; others may be reported locally to members of the survey party.

### *3237. Other Details*

Since the boat sheet is the hydrographer's work sheet, other details which are considered of possible use during the survey may be shown. Of advantage in certain types of surveys are a large compass rose and one of the several different types of

speed scales described in **4826**. These may be inked on the boat sheet in spaces where no sounding is expected.

## 324. Use of Boat Sheet During Survey

It is frequently not practicable to handle the boat sheet as carefully as one would handle a smooth sheet, nor is it necessary. The boat sheet is unavoidably subjected to somewhat rough treatment, especially in launches and small boats, but it should not be treated carelessly. The more carefully it is handled, the better will it retain its original dimensions and accuracy, and the more useful will it be as a guide in plotting and verifying the smooth sheet.

It is essential, however, that the best possible care be taken of an R.A.R. boat sheet for reasons mentioned in **3223**.

A boat sheet should not be rolled to a diameter smaller than 3 inches.

### *3241. Proposed Sounding Lines*

To survey an area thoroughly and effectively, systematically planned lines of soundings must be run. The desired system is usually indicated in a general way in the project instructions, but if not, it should be planned in accordance with **314.** The proposed sounding lines of the general system are ruled in pencil on the boat sheet as a guide to the hydrographer; only a few lines, however, should be ruled in advance because, as the survey progresses and additional knowledge is acquired of the depths in the area and of the character of the submarine relief, it may be necessary to shift the entire system slightly from time to time or to adopt a different spacing of lines.

Where the use of ranges is practicable, proposed lines can usually be followed very closely. In other cases the sounding vessel can often be kept only approximately on the proposed lines, especially where there are strong irregular currents or where the control is relatively weak. Thus two adjacent sounding lines frequently deviate from the proposed lines to such an extent that a *split* line is required to comply with the spacing requirements.

Additional lines which split the specified spacing, or lines of a superimposed system in an entirely different direction, are usually laid out on the boat sheet to guide the development of extensive shoal areas encountered during the survey.

### *3242. Proposed Development*

Every shoal indication disclosed by the systematic sounding lines (see **3154**) should be emphasized on the boat sheet by encircling the area with a red pencil, or otherwise, as a reminder that further investigation or development is required. As the soundings are inked during the progress of the survey, all danger indications and soundings which are suspected of being in error should likewise be noted for further development or investigation (see **3621**). The least depths on shoals found by prior surveys and areas in which dangers or shoals have been reported, or are suspected, should be similarly marked in color for future attention.

### *3243. Plotting Positions*

The principal use of the boat sheet is, of course, to enable the hydrographer to plot each position of the sounding vessel as the observations are made; to determine whether *on line* or not, and if not, to indicate the change in course required. As the consecutive lines of the system are surveyed and the soundings are plotted, the results

should be examined critically to determine whether the area is being adequately covered, and where additional splits or development should be added; or whether the adopted spacing is unnecessarily close. If splits and additional development are not occasionally necessary the regular system of lines is almost certainly uneconomic.

### *3244. Revision of Topography*

On an inshore hydrographic survey the boat sheet is used for indicating any changes or errors in the high-water line and in the offshore details transferred from the topographic sheets. Such corrections shall be shown in red with appropriate notes added explaining the method of location used. (See **3811**.)

Sextant cuts to locate a rock, breaker, hydrographic signal, or other feature should be carefully plotted on the boat sheet, the penciled lines being left to indicate the positions from which the cuts were taken. All pertinent data should, in addition, be recorded in the Sounding Record so that they may be plotted independently on the smooth sheet.

Isolated rocks or groups of rocks not yet accurately located should be noted on the boat sheet in their approximate positions, with notes to indicate the probable accuracy of position in case it is not practicable for any reason to locate them subsequently by a more accurate method. Where it is not practicable to locate the limits of reefs, breakers, kelp, etc., by three-point fixes, they should be sketched as accurately as possible and adequate descriptive notes should be added to guide the smooth-sheet plotter in case any such features have to be transferred from the boat sheet to the smooth sheet.

The height of each isolated rock, or the highest of a group, shall be entered in the Sounding Record, together with the date and time of observation, so that the correct tide reducers may be subsequently entered to obtain the elevation of the rock with reference to the appropriate datum plane. The approximate height should be noted on the boat sheet. (See **7821**.)

### *3245. Station Names*

All control stations used in the survey must be named on the boat sheet, and the spelling and usage of station names recorded in the Sounding Records must agree with the boat sheet. (See also **215** and **3231**.)

The symbols and names of stations appearing on the boat sheet but not used during the survey shall be crossed out in ink to indicate that they are not needed on the smooth sheet.

### *3246. Daily Inspection of Boat Sheet*

The boat sheet should be reviewed daily by the hydrographer. At this time he should plot all positions which could not be plotted during the day, and rectify the data in the Sounding Record to correspond. Corrections should be made to erroneously recorded data, omissions should be supplied while the details are fresh in mind, and notes should be made that are required to explain fully any data which are not self-evident. (See **81** and **818**.) This examination will also disclose the adequacy of the recorded data and shortcomings can be brought to the attention of the recorder.

By this daily examination, the hydrographer determines whether the area is being adequately covered and developed, whether there is agreement in depth between soundings on adjacent lines and at crossings of lines, whether there should be additional sounding on shoals and dangers, whether all previously charted shoals and dangers

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have been adequately proved or disproved, and where additional work appears necessary. Such a daily examination enables the hydrographer to keep all the necessary development and investigation up to date with the progress of the systematic sounding, and to avoid uneconomic returns to areas supposedly completed.

When practicable to do so, the Chief of Party should review the work of his subordinates daily by a similar critical and thorough examination of the boat sheet (see **3411**).

## 325. Details on Completed Boat Sheet

### *3251. Positions and Numbers*

The positions and the numbers of the positions should be inked legibly and in the assigned color as the work progresses, or at least before another day's work is begun. Expert lettering is not required. (See **3311** and **3312**.)

### *3252. Lines Connecting Positions*

The successive positions of the survey vessel along a sounding line should be connected by pencil in accordance with the instructions for the smooth sheet (see **7682**). The connecting lines should reflect any appreciable changes in course between positions.

The end and beginning of adjacent lines shall be connected by a pencil line to indicate the approximate course of the vessel, with an arrow at the midpoint indicating the direction. Sounding around turns between ends of lines is not required and should be omitted except where there would otherwise be no sounding. In this case the vessel's track around the turn should be plotted more accurately and in accordance with the instructions in **7682**. On turns in shoal water continued sounding may be needed so that the hydrographer can be kept informed as to the depth of water under the vessel, even if these soundings are not needed for the survey.

Where a sounding line parallels the sinuosities of a narrow waterway where it is impracticable to maintain straight courses between positions, or where large changes in course are made between positions, the actual track of the vessel shall be shown on the boat sheet with great accuracy because only by reference to this record can the soundings be correctly plotted on the smooth sheet.

### *3253. Soundings*

The soundings, reduced to the approximate sounding datum (see **152**), shall be inked on the boat sheet in black as the work progresses; each day's work shall be inked daily.

It is usually practicable to ink the soundings of small-scale ship surveys while the sounding is in progress; by contrast, it is generally impracticable to do this on large-scale launch surveys because of engine vibration and because the soundings and positions are taken so frequently there is no time for inking.

When it is practicable to ink the soundings as they are taken, a carbon copy of that part of the Sounding Record which contains the soundings, the clock times, and the position numbers will be found of advantage (see **81**).

### *3254. Depth Curves*

Depth curves are required on a boat sheet for an adequate study of the results of a survey, and to ensure that the area has been effectively sounded and satisfactorily developed (see **353**). The intervals between depth curves should follow the rules given

in **3533**. Depth curves should be drawn daily and revised daily to conform with the more complete information available. All depth curves should be left in pencil until it is certain that no further revision will be required. As the various parts of the area are completely surveyed, the curves should be inked, using the standard colors from table 27 in **776** insofar as they are applicable.

### *3255. Notes*

Use of copious penciled notes on the boat sheet is permitted and encouraged; for example, those made along the margin to remind the hydrographer of the need for additional development or data before leaving the field. Others are of assistance to the hydrographer in preparing the Descriptive Report, and to the smooth plotter in his interpretation of the Sounding Records and other data. Facetious and useless comments should, of course, not be included in such notes. (See **7912.**)

All notes that are of permanent value and that contain information that should be transferred to the smooth sheet shall be inked before the boat sheet is transmitted to the Washington Office. Those that will serve as directions or explanations to the smooth-sheet plotter may be left in pencil. All temporary notes and symbols for the hydrographer's temporary use only should be erased.

Where it has been impossible to survey over a shoal area because of heavy tide rips or breakers, which occur even in moderate weather, the area should be outlined on the boat sheet with a broken line in black ink, with an appropriate note explaining why the area was not sounded and giving an estimate of the least depth.

### *3256. Junctions With Other Surveys*

The approximate limits of adjoining surveys shall be shown on the boat sheet by inked lines in a distinctive color, accompanied by the registry or field numbers of the adjoining surveys (see **788**).

### *3257. Review of Completed Sheet*

After the field work of a hydrographic survey has been completed, and before the records leave his custody, the hydrographer should make a thorough examination and review of the boat sheet to ensure that all details of permanent value have been inked, and that they are unmistakably clear and legible. The use which is to be made of the boat sheet by the smooth plotter and in the Washington Office should be borne in mind. (See **3211** and **3212.**)

### 326. Shipment of Boat Sheet

The boat sheet shall always accompany the smooth sheet whenever the latter is transmitted to any other party, Processing Office, or the Washington Office. It shall be forwarded, however, in a separate package and at a different t me from the smooth sheet and the Sounding Records. Shipment may be made by registered mail or by express. A transmitting letter (Form No. 413), in duplicate, shall be mai ed separately. A triplicate of the transmitting letter shall be included in each package. For further details of shipments see **836**.

## 33. HORIZONTAL CONTROL OF HYDROGRAPHY

A hydrographic survey is a three-dimensional survey in which a sounding represents a vertical measurement of the depth of the water, which must be located in the horizontal plane by two coordinates. Obviously a knowledge of the depth is useless

for charting purposes without a knowledge of the geographic position at which the depth was measured, or its relative position with reference to the land.

The problem of hydrographic surveying is twofold, one part consisting of the various methods of measuring the depths of the water and the second part consisting of the measurements to determine positions in the horizontal plane. This latter is called *position finding*, or the horizontal control of the survey.

To determine the position of any point in a horizontal plane, at least two measurements are required, and in all methods of control, except by astronomic observations, these measurements must be to points (control stations) whose geographic positions are known, or whose relative positions to one another are known. Each measurement may be considered as resulting in a *line of position* on which the desired point is located. It is obvious, then, that it is necessary to have two intersecting lines of position, straight or curved, to determine the horizontal position of the point.

This principle is applicable both to land surveying and to hydrographic surveying. In the latter the two measurements may consist of azimuths, or directions, from or to known control stations, which result in straight lines of position; or angles measured on board the survey vessel between control stations, each of which results in a curved line of position which is part of the circumference of a circle passing through the two known points and the observer's position; or distances to known control points, resulting in distance arcs which are parts of circles of position. Analysis shows that, except for surveys controlled by astronomic observations, all position finding consists of a determination of the position of the vessel by one of the three methods or combinations of two of them.

Theoretically, the strength and accuracy of any position determination depends directly on how closely the angle of intersection of the lines of position approaches 90°. Practically, the accuracy of position determination obtainable in hydrographic surveys decreases almost proportionately to the distance from the land, until astronomic observations are used.

## 331. Positions

For proper identification, hydrographic positions shall be numbered consecutively, starting with number 1 at the beginning of each day; and each day's work shall be identified by a letter, or combination of letters assigned in alphabetical order.

When hydrography is continuous, on a 24-hour basis, the first position after midnight shall be considered to start a new day and shall be numbered and lettered accordingly, except for long dead-reckoning lines (see **3311**).

### *3311. Day Letters*

When hydrographic surveying is on a daily basis, each day's work shall be identified by a letter, or combination of letters assigned in alphabetical order, starting with the letter *A* on each survey sheet. Capital letters of one color shall be used to identify the hydrography surveyed from the ship or the major survey vessel of the party; and lower-case letters to identify the work of the supplementary launches or vessels of the party, a different color being assigned to each separate unit. These distinctive letters and colors are to be used to identify the hydrographic positions throughout the records and sheets.

Until the alphabet is exhausted, single letters shall be used for day letters, omitting the letters *O* and *I*. After the letter *Z*, double letters shall be used, the first series

being *AA*, *BA*, *CA*, *DA*, etc., the second series being *AB*, *BB*, *CB*, etc., and likewise for successive series. Primed letters, as $A'$, $B'$, etc., shall not be used.

The colors to be used to identify the numbers and day letters of the positions are blue, purple, green, and red, in that order of preference. Neither black nor yellow shall be used for this purpose.

A dead-reckoning line, controlled by astronomic sights, run in one general direction and of not more than a few days' duration, shall be considered as an entity and a single letter shall be used to identify all the positions on it regardless of calendar days.

When hydrography is continuous, on a 24-hour basis, as in R.A.R., day letters shall be changed at midnight, the first position after midnight being assigned a new day letter.

### *3312. Position Numbers*

The positions of a hydrographic survey shall be numbered consecutively for each day's work. For this purpose positions shall be understood to include, in addition to fixed positions, all positions at which control data of any kind are recorded, including log readings, astronomic sights, bearings, etc., and time data required in the plotting.

Numbered positions shall be recorded under all of the following circumstances, whether or not accompanied by control data, when this is practicable:

(*a*) At the beginning and end of each line.

(*b*) When the sounding vessel has attained sounding speed at the beginning of a line or is slowed down near the end of a line and at all other times when the speed is changed appreciably.

(*c*) At all changes in course larger than 10°. When the vessel is small and the change in course is immediately effective, the position may be taken at the middle of the change. Otherwise, a position should be taken just before the course is altered and just as soon as the vessel is on the new course. When soundings are not recorded around turns between the ends and beginnings of adjacent lines, positions are not required between the last and first sounding of each line.

In hydrography controlled by R.A.R., or any other means where fixed positions in quick succession are not practicable, a fixed position should be obtained in the vicinity of each turn where it will best control the sounding lines, other positions based on clock times or other data being recorded, by which to plot the ship's course accurately (see **6812**).

(*d*) At all abrupt and considerable changes in depth.

(*e*) At each detached sounding, including the least depth on a shoal which is being investigated. Where drift soundings are taken over a shoal for the purpose of determining the least depth thereon, several positions at which the shoaler depths are found shall be recorded in the Record. No record need be made of other soundings obtained during the investigation except that a note must be made in the Sounding Record stating the length of time spent in the investigation. (See **3666**.)

(*f*) At each sounding taken by any means with the vessel stopped, except as noted in **3313** for vertical wire soundings taken close together.

(*g*) Each time a position is fixed for any purpose whatsoever in connection with the survey, whether or not to fix the position of a sounding.

(*h*) At any incident to which it may be necessary to refer.

In recording surveys run on preestablished ranges, as in **334**, it may be desirable to identify each position by the range it is on, rather than use the customary consecutive numbering system throughout the day. The day letters should be used as usual, but positions may be identified as range 1*a*–1, range 1*a*–2, etc., in which the letter is the day letter, the first number is the number of the range, and the second number is the number of the consecutive position on that range. In the records and on the sheets the control stations should be marked to correspond with the identification used in the Sounding Record.

Where positions of the soundings are determined by linear measurements along a range, each consecutive sounding may be identified by its distance from the front range

mark or control station, as range 1*a*–8*m*, range 1*a*–16*m*, etc., in which 8*m* and 16*m* represent the distances in meters along the sounding line from the control station.

### *3313. Frequency of Positions*

The regular interval between consecutive fixed positions along a sounding line should be such that the proposed lines can be followed closely enough so that splits will rarely be necessary and there will be little uncertainty about the placement of the soundings between fixed positions. Thus the frequency of position will depend on the depths, the spacing of the lines, the scale of the survey, the bottom relief, the speed of the vessel, the length of the sounding lines, and the constancy of the current. It is apparent that some of the above are complementary; for example, where the depths are greater the lines are spaced farther apart, and the survey is usually made on a smaller scale.

A uniform frequency of position should be chosen, which can be generally maintained throughout most of the survey. This will be of advantage in plotting and spacing the soundings and will aid in detecting errors in plotting.

For handlead sounding on large scales at the proper speed of vessel, the interval should seldom exceed 3 or 4 minutes, but may be increased somewhat for offshore work on smaller scales.

A position should generally be taken at each vertical wire sounding, but when the soundings are close together and there is little likelihood of the vessel's being deflected from her course by currents or other causes, a position may be taken on every second or third sounding.

In an echo-sounding survey of an area of fairly even bottom, the maximum distance between adjacent positions on a line should be about 1⅓ to 1½ inches on the survey sheet, regardless of scale.

Where the bottom is irregular, the slope is steep, or there is difficulty in keeping the sounding vessel on line due to current, or for any other reason, positions should, of course, be taken more frequently.

When echo soundings are taken from a vessel proceeding at standard speed the distance traveled in any interval of time will be longer than at a lesser speed, but the proposed lines can be followed more closely because of this increased speed.

In most hydrographic surveys controlled by three-point fixes, the signals are readily visible and positions can be taken almost as frequently as they can be recorded and plotted. For a vessel with a speed of 8 knots, taking echo soundings controlled by fixed positions on a 1:10,000 scale, the maximum time between positions should ordinarily be about 1⅓ to 1½ minutes. For smaller scales, the times between positions may be increased slightly less than proportionately. For a 1:20,000 scale and other conditions as before, the maximum interval should probably be between 2½ and 2¾ minutes.

For surveys controlled by R.A.R., there is a practicable minimum time between successive positions because of the time needed to receive the returns, take the time intervals from the chronograph tape, and plot them on the boat sheet. In 1941 this required about 4 minutes, although developments in methods and equipment may reduce this somewhat. Only rarely are surveys controlled by R.A.R. plotted on scales larger than 1:80,000, and for this and smaller scales an interval less than 4 minutes should seldom be required. (See **6812**.)

On dead-reckoning lines controlled by astronomic sights, positions with log readings should be taken at regular intervals of about 10 minutes each. These should be supplemented by positions at times when control data are observed, as for instance at

each astronomic sight which is to be used as a separate line of position.

Where an area has to be developed by a system of lines more closely spaced than is customary at the scale of the survey, a proportional reduction in the interval between positions must be made.

The maximum interval between positions should be reduced when there is any likelihood of its use resulting in misplaced intermediate soundings or errors in the positions of the depth curves.

Although there is no objection to the use of unrecorded trial positions to check the course or distance while sounding, valuable control data are lost if they are not recorded. The fact that a trial position is required is evidence of uncertainty between fixed positions. In such case the trial position should be observed at the time of a sounding, and recorded. (See **3452**.)

## 332. METHODS OF CONTROL

The methods usually used to control hydrographic surveys depend on the distance from land and the depth of the water. In general, the accuracy with which any sounding can be located in latitude and longitude also varies proportionally with the distance from the land, until astronomic sights are resorted to.

Where the survey vessel is close to the shore, its position, or the positions of the soundings, may be determined most accurately from observations at control stations on shore. This method is slow, its reliability depends on the correlation of observations taken at widely separated points, and the accuracy attained is usually unwarranted at the scale of most inshore coastal hydrographic surveys. Its use may be warranted, however, in harbors, in dredged channels, in the vicinity of docks and piers, and where subsurface construction is to be undertaken in the area.

### *3321. By Three-Point Fixes*

The usual method of *fixing* hydrographic surveys within sight of land is known as the three-point fix method, described in detail in **333**. This method is almost universally followed for position finding. It consists in measuring simultaneously on board the survey vessel two sextant angles between objects or signals whose geographic positions are known. Where moderate depths extend a considerable distance from the shore this method may still be used to determine the position of the survey vessel beyond sight of land with reference to anchored control buoys, whose geographic positions have been determined with reference to the shore control stations (see section **25**).

### *3322. By Radio Acoustic Ranging*

Beyond the limit of visibility of shore objects and where the use of buoys for three-point fix control is impracticable or unwarranted, a number of methods of control have been used in the past—all considerably less accurate and consequently less satisfactory than fixed position determinations. The limit of visibility may be imposed by the curvature of the earth, but generally it is dependent on the atmospheric conditions in the area.

Radio Acoustic Ranging (R.A.R.) is the method employed beyond the range of the three-point fix method. It is described in detail in chapter 6. By this method the position of the survey ship is determined by the indirect measurement of distances from two or more previously located control stations. The method may be thought

of as the determination of an unknown position by the measurement of two sides of a triangle when the length of the third side is known. Each control station is equipped with a radio transmitter and a subaqueous sound receiver. The distances of the survey ship from the control stations are determined by exploding a small bomb in the water near the ship and measuring the interval of time required for the sound to travel to each station. A chronograph on the ship records the explosion of the bomb and the radio signals which are transmitted automatically by the control stations when the sound from the bomb arrives at the respective stations. If the velocity of sound through sea water is known, the distances can be computed and the ship's position thus determined.

Beyond the range of R.A.R. and in areas where such accuracy is unwarranted, soundings are fixed in position by the well-known methods of dead reckoning and astronomic observations as used in navigation, with refinements. (See **337** and **338**.)

### *3323. Other Methods*

In addition to the two methods used most to fix the position of the survey vessel during a hydrographic survey, there are a number of other methods used in special circumstances or to supplement the two more common methods. Those most frequently used are:

(*a*) Shore observations—used solely or partly to control large-scale inshore surveys—described in **334**.

(*b*) Estimation—where the positions are determined in whole or in part by estimated distances and directions to shore detail, or control stations—described in **335**.

(*c*) Bearings—where the position is determined wholly by bearings from the survey vessel to control stations (see **3361**), or by a bearing and distance, as in the following typical examples:

(1) One bearing and one sextant angle.
(2) One bearing and R.A.R. distance.
(3) One bearing and distance by vertical angle (see 3363 and 3364).
(4) One bearing and distance by depression angle (see 3362).
(5) One bearing and distance by rangefinder (see 455).

(*d*) Dead reckoning—where positions are determined by the ship's run from the last fixed position—described in **337**.

(*e*) Astronomic observations—where positions are determined by observations of celestial objects—described in **338**.

## 333. Sextant Three-Point Fixes

Hydrography shall be controlled in horizontal position, in areas where a sufficient number of suitable control objects are visible, by the well-known three-point fix method, using sextant angles, unless more precise methods are required. (See **334**.)

Position determination by two or more sextant angles taken by observers on the survey vessel is the most satisfactory and commonly used method for hydrographic surveys when the required objects are visible. To observe a three-point fix, two observers measure two angles simultaneously with sextants; one measures the angle between the left-hand and center object, and the other the angle between the center and right-hand object. The position of the vessel is then found mechanically by using a three-arm protractor (see **4534**). This is in effect a graphic solution of the three-point problem. The advantages of the method are that all of the operations are performed on board the survey vessel, the required data are known immediately, and the position may be determined quickly.

### *3331. Principles of the Three-Point Fix*

The theory of the three-point problem is well known. It depends on the following three principles:

(*a*) The circumference of a circle can be described through any three given points.

(*b*) If two of the points are fixed in position, the angle between them measured at a third point will be the same for all points on that part of the circumference of the circle on the same side of a line joining the two fixed points.

(*c*) If, in addition to the first angle, a second angle is measured from the same unknown point to two points, one of which always, and both of which occasionally, differ from the first two, the position of the unknown point will also be defined by a second circle. Since the unknown point lies on the circumferences of two circles, its position will be defined by the intersection of these.

### *3332. Strength of Three-Point Fix*

Theoretically, the strength of a position determination by a three-point fix depends directly on the angle of intersection of the two circumferences defined by the two angles and the three known points. The more nearly this intersection approaches 90°, the stronger is the fix. Conversely, the nearer the circles approach tangency, the weaker the position becomes until it is indeterminate when the two circles coincide. An indeterminate fix is called a *revolver* or *swinger* because, when an attempt is made to plot it with a protractor, the protractor will swing along the arc of the coincident circles, since any point on them will satisfy the conditions. The strength of a three-point fix, therefore, depends directly on the relative positions of the three fixed points and the unknown position.

An experienced hydrographer can visualize almost automatically the circle passing through two fixed points and his position. When he realizes that the two circles involved will intersect at an acute angle, he knows that the objects responsible for this condition must be avoided, if another choice is available. The three-point problem is analyzed in various treatises on surveying and this need not be repeated here, but beginners who may have some difficulty in selecting the most suitable objects should find the following general rules useful:

(1) The strongest fix is when the observer is inside the triangle formed by the three objects. And in such case, the fix is strongest when the three objects form an equilateral triangle, the observer is at the center, and the objects are close to the observer.

(2) The fix is strong when the sum of the two angles is equal to or greater than 180° and neither angle is less than 30°. The nearer the angles equal each other the stronger will be the fix.

(3) The fix is strong when the three objects are in a straight line, or the center object lies between the observer and a line joining the other two and the center object is nearest to the observer.

(4) The sum of the two angles should not be less than about 50°, better results being obtained when neither of the angles is less than 30°.

(5) The fix is strong when two of the objects a considerable distance apart are in range or nearly so and the angle to the third is not less than 45°.

(6) A fix is strong when at least one of the angles changes rapidly as the survey vessel moves from one location to another.

### *3333. Selection of Objects*

The theoretical strength of the three-point fix is based on the supposition that there will be no more than a certain angular error in any measured angle regardless of the size of the angle or the distance of the objects. There are other practical limitations which must be considered.

Small angles should generally be avoided as they result in weak fixes in most cases and are usually difficult to plot. A strong fix will be obtained, however, with one small angle when the vessel is a little off a range and the nearer of the two objects in range is the center object. In this case the small angle must be observed very accurately, and

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the positions of the two range objects must be very accurately known and plotted, or comparatively large errors in position will result. It should also be noted that, while such a fix continues strong as long as the near object is in the center, it may become very weak as soon as the vessel moves to a position where the more distant object is the center object.

Avoid using at close range an indefinite object or one whose position is uncertain. Errors from such sources decrease rapidly as the distance of the uncertain object increases relative to the other two. In other words, two nearby definite objects whose positions are accurate may be combined to good advantage with a right- or left-hand distant object which is indefinite or whose position is not so accurately known.

The definiteness of the objects and their accuracy of position being equal, nearer objects should always be preferred to more distant ones, since slight errors in the angles affect a position less. Possible distortion of the plotting sheet also makes it preferable to use nearer objects. For inshore hydrography, control stations on the adjacent shore provide greater accuracy than distant stations as, for instance, those on the opposite side of a wide channel or large bay.

There are numerous advantages in using off-lying signals, or those on an opposite shore, however. In many cases angles are easier to observe and plot. It is not necessary to change objects so often as when using nearby signals and the necessity for numerous closely spaced signals is avoided. The extent to which such signals can be used is therefore important and requires good judgment. In general, for ordinary hydrographic surveying it is satisfactory, and in fact preferable to use such signals, provided their positions are accurately determined, that they are so distributed that strong fixes may be obtained from them, and that they are not so far away as to require the use of extension arms in plotting. Under these conditions one or more distant signals can be used advantageously in conjunction with nearby signals. The strength of an inshore fix may be increased considerably if one distant offshore signal is used in conjunction with two signals along the shore close to the observer, the survey vessel being inside the triangle formed by the stations. The angle between the alongshore stations determines the distance of the vessel offshore, the angle to the offshore station determining the position along the shore.

If practicable, the distances between the center and the right- and left-hand objects should be longer than the observer's distance from the center object. But a very near center object is a disadvantage when used in combination with distant right- and left-hand objects from a moving vessel because of the rapidity with which the two angles change. Unless the observers stand close together and mark their angles accurately and simultaneously, there is likelihood of introducing a relatively large error in the sum angle which will affect the position considerably. In such cases, however, there will be less likelihood of appreciable errors of position being introduced if one of the observers measures the sum angle and it is used in combination with either the right or left angle. (See **7625**.)

Avoid a selection of objects which results in a *revolver* (see **3332**). Sometimes near the inshore end of a line there is no other choice; but in such a case a third angle should be taken, if practicable, to a distant definite feature such as a tangent or point of land. When the hydrographer expects such a situation, a constant course and speed should be maintained from the previous position, so that the dead reckoning may be used in conjunction with the angles in plotting the position in its correct location.

A weak fix is indicated when both angles change slowly as the survey vessel moves along the sounding line. It should be noted that the fix is strong if, in plotting, a slight

movement of the center of the protractor moves the arms away from one or more of the stations, and it is weak if such a movement does not appreciably disturb the relation of the arms to the three points.

### *3334. Changes of Fix*

Generally the strongest fix available should be observed at each position. There are other practical limits, however, to the frequency with which changes in fix should be made. Frequent changes of objects are conducive to recorder's errors as well as observer's errors. It is considerably easier for an observer to repeat angles between the same two objects than it is to find two new objects in his sextant at each observation. When signals are faint, due to distance, haze, etc., it is often much better to *hang on* to a fix, rather than attempt a change to a stronger fix. Some observers, however, tend to retain the use of the same three objects long after a change to a stronger fix should have been made.

### *3335. Sextant Fixes on Shore Objects*

In addition to the general information relative to strength of fixes and selection of objects, there are specific points that should be guarded against when fixing the position of the vessel by sextant close inshore and far offshore.

Without a multitude of small signals it is impracticable to obtain a strong fix at the inshore end of each sounding line, as a survey vessel close to the shore is nearly on line with the signals and the sum of two angles will generally approach 180°, with one of the angles being extremely large and the other extremely small. Such a fix determines accurately the distance offshore but is very weak in its determination along the shore. Since the angles of such a fix change rapidly when the vessel is moving, unusual care must be taken to mark the two angles simultaneously; otherwise there may be considerable error in the position. This also applies to inshore positions fixed by using two signals close to the observer and one distant offshore signal.

Where all the signals of a three-point fix are at short distances from the vessel, the error introduced by not marking simultaneously has less effect on the position. Where the center object is close, the effect on the position increases with the distance of the right and left objects from the observers.

At times when it is impossible to obtain a three-point fix, it is possible to measure two angles to four signals so as to fix the position. This is known as a *split fix* because there is no common center object. If the signals are appropriately chosen the fix may be just as strong as a three-point fix but considerably more time is required to plot it. It cannot be plotted by the three-arm protractor method—instead, the locus of each angle must be plotted separately, the position being at the intersection of the two loci (see **7625**). Such a fix should be taken intentionally only when no three-point fix is available.

Fixes at the extreme limit of visibility are likely to be weak because the angles between the only stations visible are generally small. In such cases the angles change slowly, and a slight error of observation affects the position a comparatively large amount because of the smallness of the angles. In such cases it is necessary to use telescopes in the sextants, to have the sextants in perfect adjustment, and to mark and read the angles with extreme accuracy.

### *3336. The Use of Indefinite Objects*

Indefinite objects or those inaccurately located shall not be used to control inshore or critical hydrography. For general use, when other objects are lacking, one indefinite

object may be combined to advantage with two comparatively near objects to form a very strong fix. For the control of offshore hydrography by three-point fixes, indefinite objects are frequently the only ones available.

*a. Hilltops.*—The tops of hills or mountains are often used as control for the offshore hydrography. Definite and conspicuous points shall be selected and these shall be accurately located so far as practicable. Round indefinite summits appear smaller and sharper at increased distances. Angles should never be taken to round-topped peaks from such short distances that there is doubt about seeing the summit. At close range, nearer points, such as shoulders and the lower slopes of the summit, are often mistaken for the actual summit, causing errors in the positions.

*b. Tangents.*—Regardless of the number of accurately located definite objects, it is occasionally necessary to include in a fix an angle to the well-defined tangent of an island, point, or other feature. Where the topography is accurate and the shoreline steep, such features can generally be used with tolerable accuracy, if they are distant as compared with the other objects. Tangents to sandy and low-lying points should be avoided.

Where the angle is measured to a tangent so distant that the juncture of the land and the water is below the horizon and cannot be seen, an error may be introduced owing to the fact that the observation is taken to a part of the feature some distance above the water and consequently some horizontal distance from the true tangent at the waterline. Even for offshore hydrography such a feature should be used only where no better objects are available. If its use is unavoidable the elevation of the feature above the true high-water line should be computed from its distance and the height of eye above the water (see **272**), the latter being recorded in the Sounding Record. The observed angle should then be plotted on the tangent of the contour that is probably on the observer's horizon. If the feature has not previously been well contoured it may be necessary to contour it especially for this purpose in order to obtain the desired degree of accuracy of position. If such a tangent needs to be used repeatedly it should be scrutinized carefully to see if there is not some distinctive natural feature at a sufficient elevation to be always visible, which may be specially located for use as a control station.

### *3337. Sextant Fixes on Buoys*

The positions of survey buoys cannot be determined as accurately as those of fixed objects on shore, and the scope of the buoy around its anchor is an additional factor of uncertainty in position at any particular observation. Because of this, proportionately stronger fixes must be used for sextant observations on buoys or the plotted positions may be considerably in error and difficulty will be experienced in running the sounding lines.

Considering a zone of hydrography to be controlled by three-point fixes on buoys established in a line, the position of the sounding vessel near the line of buoys can be determined more accurately where they are correct in azimuth with reference to one another, irrespective of the accuracy of their distances apart; and the positions far from the line of buoys can be determined more accurately where the distances between the buoys are correct, irrespective of the absolute accuracy of their azimuths with reference to one another. If sounding lines are run normal to and through the line of buoys, large *jumps* will occur when the vessel passes from one side of the line of buoys to the other, unless the buoys are accurately located in azimuth with reference to one another. If the distances between buoys are inaccurate the extreme outer end of a straight

sounding line will plot as a curve, and a large *jump* will occur when, at a considerable distance from the buoys, one or more of the buoys comprising the fix are changed.

For a method of strengthening the azimuths between adjacent buoys in a line of buoys located by sextant cuts, see **2552**.

The difficulty of observing sextant angles between survey buoys beyond sight of land is considered in **4522**.

### *3338. Inclined Angles*

Where a sextant angle is observed between two objects which do not lie approximately in the same horizontal plane as the observer, the observed angle must be corrected before it is used for plotting. Where one of the objects is at or near sea level and the other at a sufficient elevation to cause an appreciable error, the inclined angle may be corrected by the use of the graph in figure 56. This graph is based on the formula

$$\cos V_c = \frac{\cos V_o}{\cos h}$$

in which $V_o$=observed or inclined angle, $h$=angular elevation of the elevated object, and $V_c$=horizontal or computed angle. (See also **941**.)

To find the correction to an observed angle, enter the graph at the left-hand margin with the altitude angle as an ordinate and from this point extend a line horizontally until it intersects the curve representing the observed inclined angle, interpolating if necessary between the curves shown on the graph. The abscissa of the point of intersection read on the horizontal scale at the bottom of the graph will give the correction to be applied. The correction is subtractive for angles less than 90° and additive for those greater than 90°. Note that the above formula and this graph are only applicable where *one* of the two objects is elevated.

If both objects are elevated sufficiently to require correction, the correct horizontal angle may be obtained from the following formula:

$$\cos V_c = \frac{\cos V_o - \sin h_1 \sin h_2}{\cos h_1 \cos h_2}$$

in which $h_1$ and $h_2$ are the angular elevations of the two objects. Logarithmic computation will be facilitated by converting this formula into the following equivalent formula:

$$\cos \tfrac{1}{2} V_c = \sqrt{\sec h_1 \sec h_2 \cos S \cos (S - V_o)}$$

$$\text{in which } S = \frac{V_o + h_1 + h_2}{2}$$

A convenient form for using the formula is as follows:

| | |
|---|---|
| $V_o$ - - - - - - - - - - - - - - - - - - - - - - - - - | |
| $h_1$ - - - - - - - - - - - - - - - - - - - - - - - - - | *sec* - - - - - - - - - - - - - - - - - - - - - - - - - |
| $h_2$ - - - - - - - - - - - - - - - - - - - - - - - - - | *sec* - - - - - - - - - - - - - - - - - - - - - - - - - |
| 2) ______________________ | |
| *S* - - - - - - - - - - - - - - - - - - - - - - - - - | *cos* - - - - - - - - - - - - - - - - - - - - - - - - - |
| *S*-$V_o$ - - - - - - - - - - - - - - - - - - - - - - - | *cos* - - - - - - - - - - - - - - - - - - - - - - - - - |
| | 2) ______________________ |
| ½$V_c$ - - - - - - - - - - - - - - - - - - - - - - - - | *cos* - - - - - - - - - - - - - - - - - - - - - - - - - |
| $V_c$ - - - - - - - - - - - - - - - - - - - - - - - - - | |

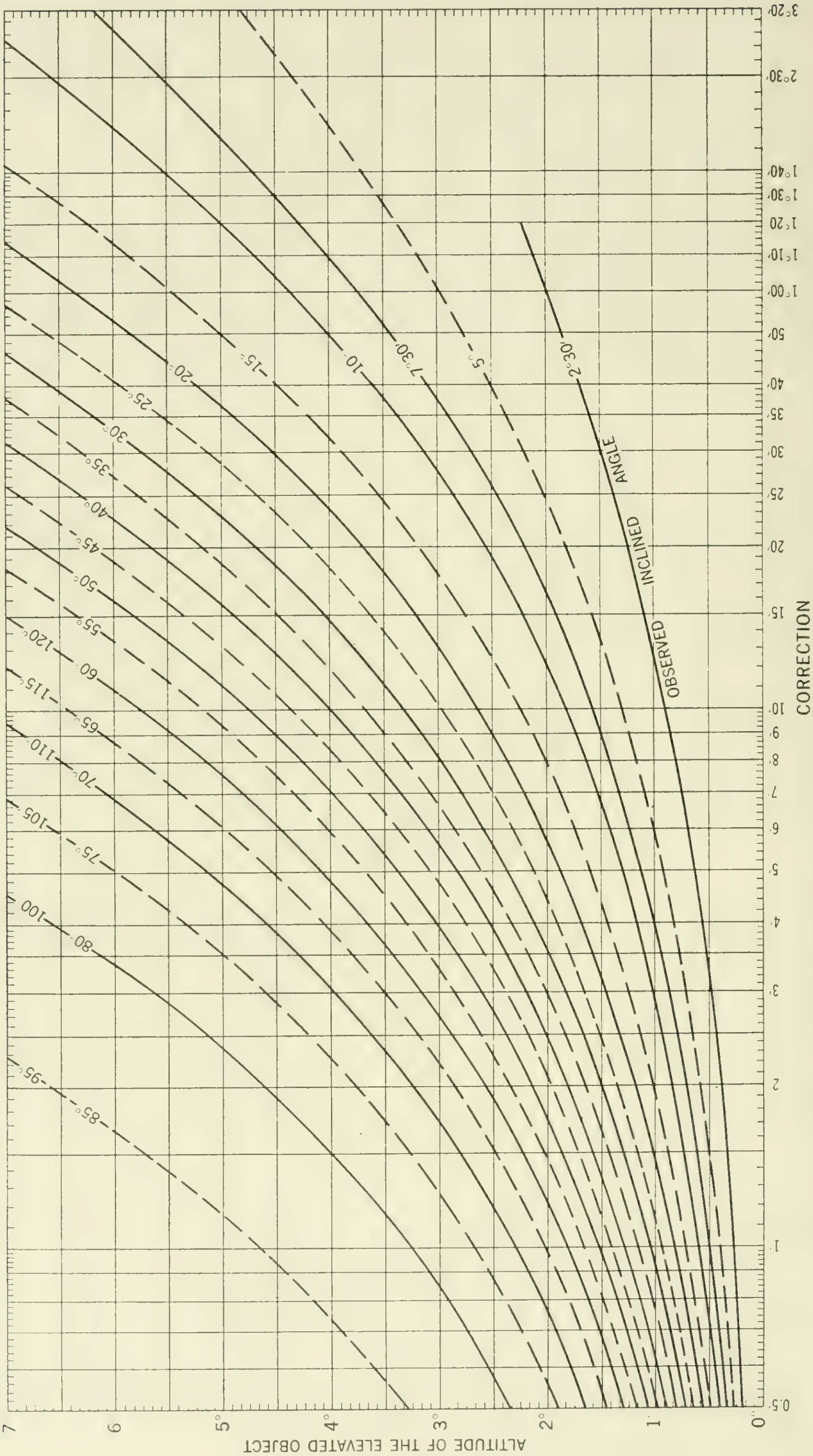


FIGURE 56.—Corrections to inclined sextant angles when one object is elevated appreciably above sea level.

## 334. LARGE-SCALE SURVEYS

More precise methods of control on larger scales are necessary for unusually intense surveys of important localities, or detailed surveys to verify dredging operations in the vicinity of docks or slips or for use in planning subsurface construction of any kind.

The methods to be used in such cases may be grouped in three classes:

(*a*) Surveys controlled entirely on board the vessel.
(*b*) Surveys controlled entirely from shore.
(*c*) Surveys controlled partly on board and partly ashore.

### *3341. Surveys Controlled Entirely on Board*

Surveys on particularly large scales (usually larger than 1:10,000) may be controlled entirely on board the vessel with the usual sextant three-point fix method, but special precautions must be taken to guard against errors that would not be appreciable on smaller scales. The control must be located more accurately. The survey vessel must proceed at slow speed and the strongest fixes must be chosen. The observers should stand close together and close to the sounding apparatus when marking the angles. The angles must be marked simultaneously. The soundings must be vertical. The exact times of soundings and positions must be noted with great care.

It is impracticable to make such a survey satisfactorily without ranges. Parallel ranges equally spaced may be established in advance for the special use of the hydrographic survey party, or if a prominent object in the distant background is where it can be seen throughout the area to be surveyed, it may serve as the rear range mark to a series of accurately located front range marks along the shore. In the latter case the sounding lines radiate from the rear object, but if it is sufficiently distant, the divergence in the spacing between lines may not be detrimental; in fact it may be advantageous as it results in a spacing increasing proportionately to the distance offshore, which may be desirable if the depths of water increase as one goes offshore. Radiating lines are of particular advantage for surveying around points of land.

For most precise operations, ranges on shore, either parallel or radiating, should be established by a topographic party, the distances between them being measured with a tape.

### *3342. Shore-Controlled Surveys*

For surveys of the greatest accuracy in river and harbor work the positions of the soundings are determined by means of two or more theodolites or transits set up on shore at suitably situated triangulation stations. Two stations will usually be sufficient to determine positions, but three are advisable to provide for a check at each position and to ensure that a position is obtained in the event that one shore observer misses his observation because of an intervening object or for any other reason.

In the most precise surveys, the depth of water permitting, the depths are measured in feet and tenths on a graduated pole, simultaneous cuts being taken from the instrument stations on shore when the pole is in a vertical position. When a position is required the shore observers are notified by a flag being displayed on the vessel; this is dropped at the instant the observation is required. Rarely is every sounding so located; it is usually sufficient to locate only every third or fourth sounding, according to the accuracy demanded.

The soundings on the vessel must be coordinated with the shore observations and it is essential that the timepieces used be in agreement, and if practicable be compared several times a day, and if necessary reset. The times of the positions and of the

shore observations should be noted to the nearest second and recorded in the Sounding Record on the vessel and in notebooks at each shore station together with the respective observations.

The directions measured with the theodolites or transits on shore must be referred to a known direction or azimuth and the object used for orientation should be verified and noted at the beginning of each page of the record by recording a pointing on the reference object. For plotting the positions of the soundings graphically, it is advantageous, although not essential, that the control stations be within the limits of the survey sheet; and it is convenient, although again not essential, if the reference station used for orientation is to the shore observer's left as he views the area being surveyed.

Directions measured with theodolites or transits should be read and recorded to the nearest half-minute; additional accuracy is unwarranted for graphic plotting.

The disadvantages of the method are that the hydrographer cannot plot the positions of the vessel as the work proceeds and that ranges must be provided for controlling the course of the vessel; otherwise a straight line of soundings cannot be run.

### *3343. Surveys Controlled Partly on Board and Partly Ashore*

The survey may be accurately controlled by stationing one shore observer at a control station with a theodolite or transit to observe a direction to the vessel at each position, while on board the vessel a sextant angle is simultaneously measured between two objects so located with reference to the occupied shore station that the circle defined by the locus of the observed angle will intersect the observed direction as nearly at right angles as practicable. (See **2522**.) The positions are plotted by laying off each direction line from the shore station and, with a three-arm protractor, plotting each sextant angle so that its vertex falls on the respective direction line.

If a series of equally spaced control stations are accurately located along the shore and successively occupied for measuring directions to the vessel, the shore observer can also direct the vessel on course with his instrument, if sounding lines are run toward and away from him, thus eliminating the need for ranges.

### *3344. Soundings Located by Measured Distances*

For still greater precision and on larger scales, e. g., 1:1,000, it is generally necessary to stop the boat for each sounding at predetermined distances from the front range marks. For an accurate survey in the vicinity of a pier or wharf, equally spaced control points may be established by taped distances along the edge of the pier or wharf. The sounding lines are generally run normal to the line of control points although they can be run at any selected direction therefrom. The boat is controlled on line by an observer at the control point who marks its progress with a transit or sextant, signaling it from time to time to keep it on line.

Equally spaced soundings are generally taken at predetermined distances from the control points by direct measurement with a line, either marked at equal intervals or run over a registering sheave. Stranded sounding wire fastened to a ring or loop, marked at equal distances by white rags inserted in the strands, will serve admirably for this purpose. A reel should be provided by which to pay out or reel in the sounding wire. The zero end of the wire may be on the boat or at the control mark. If on the boat, a man is stationed at the control point with the reel; the boat proceeds slowly along the predetermined line and at the proper intervals it is stopped for soundings by braking the reel. If the zero end is at the mark, the reel is on the boat and the boat is stopped by a member of the crew applying the brake. All lines must be run away from the

control points; this method of direct measurement cannot be used satisfactorily when proceeding toward the control point.

### *3345. Use of Portable Range Marks*

Where it is impracticable to set ranges on shore for use in running the sounding lines, use can often be made of a small skiff manned by one or two men, on which a flag is erected. The desired spacing of lines is selected and an anchor line marked accordingly. The skiff is anchored to one side of one end of the area to be surveyed. By means of oars the skiff is propelled in a direction normal to the desired system of lines and stopped at each mark on the anchor line. It is held in place normal to the direction of the sounding lines by an occasional dip of the oars while the line is being run. For each successive sounding line the anchor line is slacked away permitting the skiff to move, normal to the direction of the sounding lines, to the next position marked on the anchor line where it is again held in place to serve as the range mark for the next line, and so on until all the desired lines have been run.

The flag in the skiff serves as the front range mark and an extremely distant object may be selected to serve as the rear range mark. If sufficiently distant the same object may serve as a rear range mark for the entire area or different points near it may be selected by estimation.

In using this method the ranges serve only to control the direction of the lines and keep them straight and do not otherwise serve as part of the control, the positions of the boat being entirely fixed either by directions from shore stations or by the usual sextant three-point fix method.

## 335. POSITIONS BY ESTIMATION

It is often impracticable to provide a sufficient number of control stations so that every position of the inshore hydrography can be fixed by a three-point fix. Positions near the beach on the inshore ends of lines, in small bights, and up narrow winding creeks and sloughs often cannot be fixed by sextant angles. It is customary in such cases, and the necessity is recognized, to estimate a small percentage of the positions. This is the most difficult part of position determination in inshore hydrography.

The estimation of distances at sea is made more difficult by the fact that there are no objects of known size by which to make comparisons. Long experience will be of assistance, but the experience of a topographer in estimating distances along the shore does not necessarily make him expert at estimating them from a launch or vessel at sea. In the estimation of short distances the height of eye plays an important part, and one who is accustomed to estimating such distances from the bridge of a large vessel at a considerable height above the water invariably overestimates the same distance from a much lower height of eye in a launch. The general tendency in estimating distances from a moving vessel is to underestimate distances to objects ahead and overestimate distances to objects abeam.

### *3351. At Inshore Ends of Lines*

Where it is impracticable to fix the inshore end of a sounding line with a three-point fix when approaching the shore, the hydrographer should obtain a good three-point fix as near to the end as practicable and maintain the same course and speed to the end of the line, if this can be done without endangering the boat and its personnel. If it is necessary to slow down on approaching the shore, a fixed or estimated position should

be obtained at the time of slowing down, the same course should be maintained, and at the end of the line the distance from the high-water line should be estimated. One angle, or a bearing, can often be obtained and combined with the dead reckoning to provide a more accurate position than can be obtained by estimation (see **7625**).

Along an irregular coast it is impracticable to provide a sufficient number of signals to fix the beginnings and ends of lines in all of the small bights and indentations into which lines should be run. An estimated distance to the high-water line or distances and directions to irregularities in the shoreline will provide sufficient control.

### *3352. Curved Sounding Lines in Winding Waterways*

In narrow winding waterways it is often impracticable to provide a sufficient number of signals from which to fix the position of the sounding vessel frequently enough to define its exact course. The sounding lines frequently parallel the shore and where the course of a narrow stream is winding, the hydrographer must fix his position with reference to control stations when practicable, at other times estimating positions with reference to the adjacent shoreline features and from his sense of dead reckoning. The sounding lines must frequently conform to the curves of the shoreline, even between fixed positions where it is impracticable to run a straight course from one position to the next. The hydrographer must estimate the course and position of the sounding vessel, plotting this course on the boat sheet from estimated distances and dead reckoning. In such cases notes should be made in the Sounding Record that the courses between fixed positions are not straight and direct, and that they should be taken from the courses sketched on the boat sheet.

Such a lack of control is authorized only where the waterway is unimportant, its average width is less than 200 meters, and the establishment of the required control would be exceedingly uneconomic. The lack of fixed positions should be compensated for by additional positions referenced to natural features and most complete notes in the Sounding Record, but irrespective of this, the smooth plotter will have to rely on the boat sheets to an unusual degree for the positions of the sounding lines.

### *3353. Distances to Objects Abeam*

The hydrographer must note in the Sounding Record the distance each object in the water area is passed close abeam. The distance should be referenced to the sounding line or lines that pass nearest the object. Such distances should be measured by depression angle (see **3362**), when this is practicable, rather than be estimated. The exact height of eye must be recorded in the Sounding Record, together with the depression angle. Among objects to which this applies are navigation and survey buoys, rocks (sunken, awash, and bare), isolated clumps or streamers of kelp, piles or fish stakes, and in fact any fixed or anchored object which may be a danger or an aid to navigation.

It is very disconcerting in plotting the smooth sheet or in chart compilation to find that the hydrographic party has passed close to an object of the nature described above without mentioning it in the Sounding Record. Some doubt is raised as to its actual existence, or whether it was visible at the time of passing.

Such data are intended to verify the existence and positions of such objects and should never be substituted for a more accurate means of location, when such is practicable.

## 336. Bearings and Distances

Inasmuch as a bearing from the survey vessel to a control object is a line of position, it is obvious that the position of the vessel may be determined by any additional data which will provide a second line of position to intersect the bearing at an appropriate angle. The more nearly this intersection approaches 90° the stronger will be the determination of the position, assuming an equal reliability in the data.

The line of position to intersect the bearing may be provided by data obtained in any one of several ways: For example, by a horizontal sextant angle measured between two control stations so situated that the locus of the angle intersects the bearing appropriately; by an R.A.R. distance from the station to which the bearing is measured or from any other station so located that the distance arc will intersect the bearing at an appropriate angle; or by a distance based on a vertical or depression angle, or measured by rangefinder.

Where a survey is controlled principally by three-point sextant fixes on survey buoys or by R.A.R. methods using sono-radio buoys, useful positions are frequently obtained by the combination of a bearing and distance measured to a buoy being passed at a short distance. Distances measured with a 1-meter rangefinder for this purpose should not much exceed 1 nautical mile; longer distances are likely to be in error more than a position controlled by other methods. (See **455**.)

### *3361. Bearings*

Directions to the survey vessel from shore positions can be observed quite accurately but are practicable only when the survey vessel is plainly visible from shore. They are ordinarily used only in connection with the large-scale surveys described in **334**. The observation on board the vessel of all of the position data is an important consideration.

Bearings from the survey vessel to control stations are frequently useful to supplement other methods of control in special circumstances, but they are notably untrustworthy from distances greater than a few miles.

Bearings from the survey vessel to control stations are ordinarily measured by means of some form of a pelorus (see **4434** to **4437**). Their accuracy depends directly on the stability of the survey vessel, and on the accuracy with which the magnetic variation and the compass error are known, unless the vessel is equipped with a gyrocompass. For best results a pelorus equipped with a telescopic alidade should be used (see **4435**), although a small theodolite mounted on the wing of the bridge of the vessel may be substituted therefor with good results (see **4436**). In any case, tests must be made to ensure that the pelorus or other instrument is correctly alined with the lubber's line of the compass (see **4437**).

Successive bearings should be observed to a distant control station to strengthen the plot of a dead-reckoning sounding line where more accurate control is lacking. The simplest case is, of course, the well-known bow-and-beam method used in navigation for determining the position of the vessel when it passes abeam of an object, the distance off being equal to the distance run by the vessel between the two observations. Where bearings such as these are used in connection with dead reckoning, it is usually more convenient to take them at regular intervals when the log is read and to adjust the read-reckoning plot graphically to the plotted bearings (see **3378**).

Inasmuch as a bearing is an angular measurement, any inaccuracy will affect the horizontal positions by a proportionally greater amount as the distance of the vessel from the object increases. Even at considerable distances, however, the data may be

of value to assist in controlling a dead-reckoning line of soundings. If the survey of an offshore area is controlled by astronomic observations, the positions of the sounding lines may frequently be strengthened by the observation of numerous bearings on an isolated island which is passed by the sounding line at a considerable distance.

For the survey of an isolated shoal one survey buoy is frequently anchored at the approximate center of the shoal, the area being developed by a system of sounding lines radiating from the buoy. Bearings are useful to control the sounding lines in azimuth relative to the buoy, the distances from the buoy being determined by vertical or depression angles or dead reckoning, as described in **368.**

### *3362. Distance by Depression Angle*

The distance between the survey vessel and an object at sea—usually, but not necessarily, a survey buoy—may be determined by the measurement with a sextant of the small depression angle between the waterline at the object and the horizon beyond. The distance varies with the observed angle and the height of eye of the observer; for a given horizontal distance the greater the height of eye the more accurate will be the determination. The distance may be computed from the furmula

$$D=\frac{H\cot(\alpha+d)}{3.28}$$

in which $D$ is the distance in meters to the object, $H$ is the height in feet of the eye above sea level, $\alpha$ is the observed angle, and $d$ is the dip of the sea horizon.

The dip may be taken from a table which will be found in any epitome of navigation (e. g., table 18 in the American Practical Navigator—Bowditch) or may be computed from the formula

$$d=59''\sqrt{H}$$

$d$ and $H$ being the same as above.

Tables or curves as illustrated in figure 57, showing the distances in meters for various angles and heights of eye may be prepared to facilitate the computation if frequent use is to be made of such angles.

This formula does not include any correction for curvature or refraction. It should be used only for short distances. Table 11 in Bowditch (page 138) is based on this formula.

The height of eye should be determined and the sextant angles should be measured accurately. The sextant should be in adjustment or a correction made for any index error. The vessel on which the observer is stationed is unstable, and if the object is a survey buoy, it too is unstable, due to the motion of the water. The angle should be marked at a time when the vessel is on an even keel and when the level of the sea at both the vessel and the buoy is as near average as can be estimated. The buoy rises and falls with the waves and an attempt must be made to measure the angle to the mean position at which the buoy would rest if the sea were calm.

Used in conjunction with three-point fix control, a depression angle of 3° or more will usually give the required accuracy; and if an observation from the bridge of the vessel would result in a smaller angle, an attempt should be made to measure the angle from a greater elevation. In general, a depression angle of 1° or less will be too inaccurate for use in connection with any kind of well-controlled hydrographic surveying. An angle of 1° will correspond approximately to a distance 50 times as great as the height of eye.

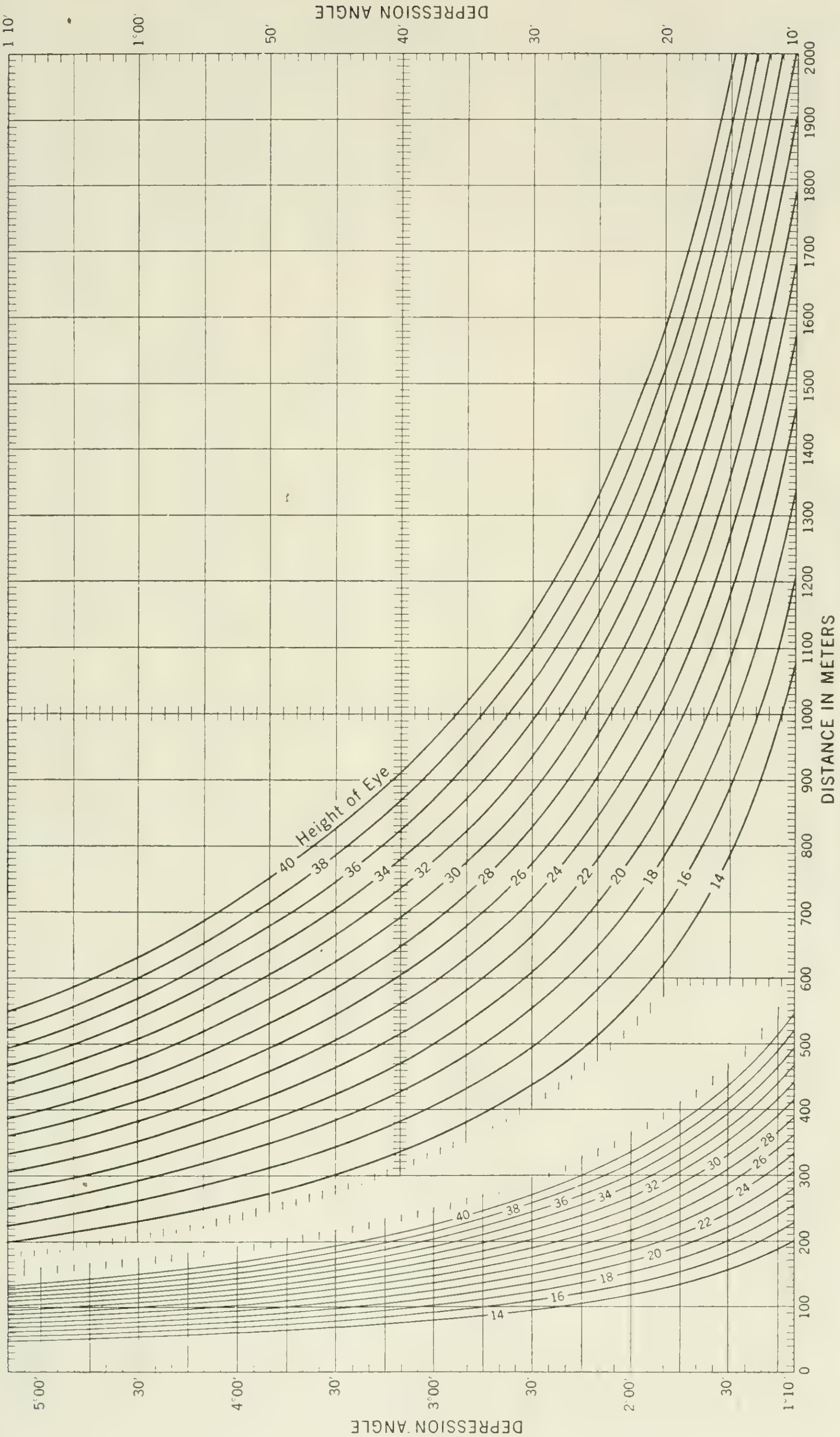


FIGURE 57.—Distance by depression angle below horizon.

### *3363. Distance by Subtended Vertical Angle*

When the horizon is indistinct, or there appears to be abnormal refraction, or if for any other reason the depression angle method cannot be used, distances to near-by objects or buoys may be determined from vertical angles measured between the waterline and the top of the object, the height of the object being known. In constructing survey buoys, the banners on each type of buoy should always be placed at the same height above the barrel for possible use in the measurement of such angles. The formula for determining the distance is

$$D=\frac{h \cot \alpha}{3.28}$$

in which $D$ is the distance in meters to the object, $h$ is the height in feet of the object, and $\alpha$ is the observed angle. This formula includes no correction for curvature or refraction. Table 9 in Bowditch (page 131) is based on this formula.

The variables in the formula are the observed angle and the height of the object, neither the dip nor the height of eye entering into it. The accuracy of the observation is increased by having the eye as close to the water as practicable and, of course, the object or buoy must be vertical at the time of the observation. Such observations are often impracticable on buoys because they are usually canted more or less by current or wind. If the object is nonfloating and its elevation above mean high water is used as the height, it must be corrected for the difference between mean high water and the height of the tide before applying the formula; the difference being additive when the height of the tide is below the plane of mean high water.

### *3364. Distance by Vertical Angle Above Horizon*

Where the object is comparatively distant and the formulas in **3362** and **3363** are inapplicable, the distance may sometimes be determined by a vertical angle measured to the object above the visible horizon. Distances so determined are rarely of sufficient accuracy to be used in conjunction with control by three-point fixes or R.A.R. They may occasionally be of value to supplement sounding lines controlled by astronomic observations or dead reckoning.

The formula is

$$D=1.15\left(\sqrt{h-H+\left(\frac{\alpha-d}{0.98}\right)^2}-\frac{\alpha-d}{0.98}\right)$$

in which $\alpha$ is the vertical angle in minutes of arc; $D$ is the distance in nautical miles; $d$ (or dip) equals $0.98\sqrt{H}$; $h$ is the elevation of object in feet above sea level at the time; and $H$ is the height of eye in feet above sea level.

The formula is adequate for most distances and convenient to use; refraction and curvature are included. The formula is applicable whether the visible horizon is between the observer and the object or the object is between the observer and the visible horizon. Table 10 in Bowditch (page 133) covers this case but has not been computed from this same formula and does not cover all possible conditions.

### *3365. Ship Stations*

In launch or small-boat hydrography it may sometimes be desirable to supplement the existing control, because of its distance, by using the foremast of the survey ship as

a signal. The ship should be anchored with as short a scope of chain as practicable and its position determined by observers on board whenever there is any change due to change in direction of wind or current; unless, of course, it is practicable to moor the ship fore and aft. The position angles by which the foremast is located and the time of taking them must be noted and subsequently copied into the Sounding Record of the survey.

The foremast of a ship anchored for this purpose may be used either in conjunction with other signals for three-point fixes or as an isolated buoy, the launch's position from it being determined by bearing and vertical angle. In the latter case it is essential that the vertical distance from some selected part of the masthead to the waterline be measured accurately and all vertical angles be measured between these points (see **3363**).

### *3366. Tandem Control*

It may occasionally be desirable to have two or more adjacent sounding lines run simultaneously and controlled by one ship, the other ships or launches being merely referenced to it.

When visual control is used and the visibility is such that sextant angles can be measured only by observers stationed at a considerable elevation, a line run by the survey ship may be controlled by three-point fixes in areas where observers on launches cannot see the signals from their lower elevation. It may be advantageous to survey the inshore lines around a distant reef by this method. The survey ship may follow the edge of the reef at a safe distance, its course being more or less paralleled by one or two launches running lines between it and the edge of the reef. In this case all of the lines can be controlled best on the survey ship at each three-point fix position. In addition to the two angles of the fix, a horizontal angle is measured to each of the launches to provide a bearing, and a depression angle is measured to each to provide a distance.

A signal is given on the survey ship by whistle, or otherwise, at each position. Generally, the inshore launch follows the edge of the reef as closely as safety will permit, changing course only on the fixed positions unless changes between positions are required for purposes of safety. If a second launch is used it should be instructed to maintain a position about halfway between the ship and the inshore launch.

The same method may be used to run parallel lines except that provision should be made for the launch to measure and maintain a fixed distance and direction relative to the survey ship. The distance may be measured by the masthead method of measuring a vertical angle between the waterline and a definite point near the top of one of the masts of the survey ship or by the use of a rangefinder.

A similar method may be used in R.A.R., if for any reason it is desired to survey with two ships in conjunction, one of which is not equipped for R.A.R. The survey ship equipped for R.A.R. controls its course by R.A.R. fixes in the usual manner, the auxiliary vessel following it on a parallel course and maintaining a constant position from it, a little abaft its beam and at a desired distance. At each fixed position the auxiliary vessel measures a compass bearing and a rangefinder distance to the survey ship. When the ships are sufficiently close, the time of each fixed position may be obtained on the auxiliary vessel by watching the bomber throw the bomb overboard; or the auxiliary vessel may be notified by any prearranged system of signals from the survey ship. The line of soundings run by the auxiliary vessel cannot be plotted at the time, but at convenient intervals the position data may be radioed to the R.A.R.

ship where the tracks of both ships are plotted on the boat sheet. Unexpected shoal soundings should also be radioed to the R.A.R. ship.

To assist the auxiliary vessel in maintaining station, all changes in course made by the R.A.R. ship should be communicated to the auxiliary vessel by flag signals or by radio.

At the end of a pair of sounding lines a standard maneuver should be followed to place both ships on the next pair of sounding lines to be run, without risk of collision. In such operations the auxiliary vessel is always kept on the same side of the survey ship regardless of the direction of the lines. In turning at the ends of lines to start a new pair of lines, assuming that the turn is to the left, the right-hand ship turns about 90° to the left, passing astern of the other ship, which maintains its course for a distance equal to the spacing between lines. The latter then turns 90° to the left and runs to the next adjacent sounding line, turning again 90° to the left and steadying on the new course. Meanwhile the ship which was to the right originally has continued on its course for a distance equal to three times the spacing between lines and then turns to the left onto the new course. When this maneuver is correctly executed the ships will be exactly abeam at all turns and at a distance from one another equal to the spacing between lines. By maintaining relative distance by rangefinder and executing the turns accurately both are in position to start the next pair of lines very close to the desired positions. To make a similar turn to the right the maneuvers of the two ships are, of course, exactly reversed.

When it is necessary to turn onto new lines where the above maneuvers are impracticable, the auxiliary vessel should be instructed by radio to fall back to the quarter or astern of the survey ship and maintain position there until the survey ship has got into the position desired to start the new lines. The auxiliary vessel can then take her position.

Some disadvantages of the method are:

(*a*) That it cannot be used at night or when the two ships are not clearly intervisible.

(*b*) The officer-in-charge of the auxiliary vessel cannot plot his data at the time, nor know how much development is required, nor whether it is being achieved. His job is merely to follow instructions.

(*c*) More than ordinary care and judgment are required in making turns where a close spacing of lines is required.

## 337. Dead Reckoning

Dead reckoning in hydrographic surveying is neither more nor less than dead reckoning as practiced in navigation, with refinements. Dead reckoning enters, in more or less degree, into practically all of the methods for determining the position of the survey vessel. Rarely is each individual sounding fixed in position, and when this is not done, the positions of the intermediate soundings are determined by dead reckoning with reference to the fixed positions. Dead reckoning is used to verify positions of doubtful accuracy, and in Radio Acoustic Ranging it is frequently used to aid in evaluating the data (see **7634**).

Dead reckoning is navigation *by account*, or reckoning, from the last known position. It is the procedure by which the position of a vessel at any instant is determined by applying the *ship's run* to the last well-determined position, using for the purpose the course steered and the distance traveled, generally as indicated by log.

From its very nature, dead reckoning is far from exact, its accuracy depending on the estimate of the run which is always apt to be more or less in error. A position determined by dead reckoning is likely to be in error by an amount proportional to the distance from the last known position. Errors which are scarcely subject to measurement may be introduced in a number of ways; among those affecting the course are imperfect steering, incorrect allowance for compass error, leeway, and current; and among those affecting the distance are imperfect logs or unknown log factors, and incorrect allowance for current.

### *3371. Prevalent Uses of Dead Reckoning*

Besides its use to supplement fixed control, the most extensive uses of dead reckoning in hydrographic surveying are to control or assist in controlling the position of the survey ship beyond the range of control stations and to supplement astronomic observations. Hydrography beyond the range of control stations should not be controlled by dead reckoning for more than 8 consecutive hours, weather permitting astronomic observations; lines taking more than 8 hours should be planned to be fixed by astronomic sights. The three commonest cases in which dead reckoning is used are:

(1) Where the control stations cannot be used to the limits of the area to be surveyed. In this case the dead-reckoning lines are run offshore, usually normal to the trend of the coast, to the limit of the area. The dead-reckoning line is almost always an extension of a well-controlled sounding line, fixed by the usual methods as far offshore as possible. The fixed positions farthest seaward aid in determining the correct course to be steered offshore and give a value for the leeway and current at the beginning of the loop. As the ship proceeds seaward the course is changed to allow for estimated variations in leeway and drift, thus maintaining the course to be made good, insofar as it can be estimated. When the ship arrives at the offshore limit of the area being surveyed, the course is changed about 90° for the run between adjacent sounding lines; it is then again changed about 90° to a course opposite to the original one until a fixed position can be obtained by conventional methods. This last course should be established by taking into consideration the estimated leeway and drift and continued without change, except for allowance for variation in leeway and drift, until a fixed position has been obtained. The line should be continued for several positions after the first fixed position, to establish the course made good and the log factor at this end of the line. Account should be taken of the turning radius of the ship at the two turns at the offshore end of the line (see **3373**).

Between the fixed positions farthest offshore other partial data should be obtained whenever possible to aid in the adjustment of the line (see **3378**). Such a dead-reckoning loop is rarely long enough for astronomic observations to be of much value, but loops of more than 8 hours' duration should be planned so that the outer end may be fixed astronomically. In the latter case clear weather should be selected and the line should be started at a time for the outer end to be reached at dawn or dusk, when a good set of stellar observations may be obtained. Such observations should be taken on the short course between the two sounding lines.

(2) Short loops similar to the above may be run radiating from a buoy, usually centrally located on a shoal. In this case the lines are comparatively short, and astronomic observations are of no value. Such lines usually start from a position close to and abeam of the buoy, the nearer positions being fixed by bearings and vertical

or depression angles, the remainder being controlled by dead reckoning. Positions should be spaced approximately 6 or 7 minutes apart, the logs and time being recorded in addition to any other data. If a sono-radio buoy is used, a distance to it can be obtained at each position and supplemented by other dead-reckoning data.

(3) To supplement astronomic observations. In this case the lines are long, with no more than minor changes in course between the astronomic data. Such dead reckoning is similar to that used by every mariner, except that it is carried out with greater precision.

### *3372. Importance of Accuracy*

The accuracy and hence the value of dead reckoning depends on the precision with which the various elements entering into it are known and are observed. The true course should be known within 1° and, if a gyrocompass is not used, the deviations of the magnetic compass should be from a recent ship swing; and, if a gyro pilot is not used, an experienced helmsman must be selected who can be trusted to maintain an average course within a fraction of a degree. The officer on watch should check the course frequently.

Currents are not observed, but the effect of the current at the beginning and end of the line may be deduced from the fixed positions, and its estimated effect, as well as the estimated leeway, must be applied throughout the dead reckoning. The possibility of a change in current during the run must not be disregarded. Leeway is probably the most uncertain of all corrections. The log factor should be known within two decimals.

The probable error in each of these elements is small in comparison with the length of the lines, but to attain the required accuracy all must be observed with more than average care and precision.

### *3373. The Dead-Reckoning Course*

If the vessel is not equipped with a gyrocompass, it is essential to keep the magnetic compass adjusted so that courses steered by it will be nearly magnetic. Unless the deviation card is based on a recent ship swing, several of the values used should be verified either before or during the running of the dead-reckoning line.

The courses on long dead-reckoning lines can be set by reference to the standard compass, but where comparatively short loops are involved it is advantageous to know the deviations of the steering compass accurately enough so that all courses may be set directly by it.

It is important that the course be accurately steered and an experienced helmsman should be selected to steer all dead-reckoning lines, unless the ship is provided with a course recorder, from which the average courses steered can be subsequently determined.

The course can be more easily and accurately steered in a smooth sea and, since dead-reckoning loops are usually only a small percentage of the entire survey, they should be undertaken only during the most favorable weather. In a rough sea it is very difficult to maintain the ship on the correct heading on certain courses, for example, when there is a following sea.

Large changes in course should be kept at a minimum in dead reckoning and all proposed lines should be planned with this in mind. Changes in course of 15° or less can be assumed to be effective at the middle of the ship's swing and a record of the time and log reading at this point is sufficient. When the change is more than 15° the time

and log reading should be noted both when the ship starts to swing and when she has straightened out on the new course. An officer should observe the compass at such times and mark the time for the recorder; otherwise the time is apt to be recorded too early at the beginning of the turn and too late at the end. For dead reckoning on large scales the ship's course should be plotted as a curve for changes in course larger than 15°, using the ship's known turning radius for this purpose (see **7682**).

The courses steered should take into account the effect of the wind, sea, and current insofar as these effects can be estimated, so that the courses plotted after correction for these effects will coincide with the proposed lines.

### *3374. Dead-Reckoning Distances*

It is axiomatic that positions on a short dead-reckoning line will be proportionately more accurate than positions on a longer line. It is important, therefore, to plan dead-reckoning loops so as to be beyond the range of fixed control for as short a time as practicable.

The faster and more constant the speed of the vessel the better can the dead reckoning be maintained. The engine room should be notified when a dead-reckoning line is to be started and warned to maintain the revolutions at as constant a rate as possible. The effect of leeway is minimized in proportion to the speed of the vessel and its application is easier when the speed is constant.

Echo sounding now permits soundings to be taken continuously at standard speed. The ship does not have to be stopped nor slowed down for soundings as was formerly necessary. For best results, the speed should be maintained at a constant rate and the ship should never be stopped during a dead-reckoning run. However, other considerations may necessitate this, such as the safety of the vessel or the need for obtaining serial temperatures at the outer limits of the survey. But so far as the dead reckoning alone is concerned, much more accurate results will be obtained by eliminating all stops and changes of speed.

At least two accurately rated logs should be used in all dead reckoning (see **4454**). If the ship is equipped with an electric submerged log (see **4452**), several of the difficulties encountered in connection with conventional patent rotating logs will be eliminated. The submerged log records correctly the distance traveled by the ship around turns. When a rotating log is used, *log loss* can be ignored for changes in course less than 15°, but for larger changes it is necessary to substitute time for log readings around the turns and for a period of several minutes thereafter. Around turns a patent log follows a course through the water shorter than the ship's course and friction on the line is often greater than normal, making the log unreliable at such times. After any change in course larger than 15° the operation of the log should be observed until it is normal, when its reading and the time should be recorded. (See also **3381.**)

If a buoy is passed close-to while patent logs are streamed, the ship should always be kept to leeward of the buoy and not too close to it, because of the danger of fouling the log line on the buoy or its anchor line. Also when patent logs are used on dead-reckoning lines started at buoys the survey ship must be placed on the proposed line 4 or 5 minutes running time before the buoy is reached in order for the logs to attain normal operation during this period.

The revolution counter should be read at positions, so that these readings may be substituted for log readings any time the logs fail to function properly for any reason whatsoever, and to furnish a check on the constancy of the speed.

### *3375. Wind and Current*

Dead reckoning can be run most accurately in a dead calm, but this condition cannot always be waited for. Experiments should be made to determine the amount of leeway which will be caused by winds of different velocities at various angles to the survey ship's heading.

An allowance must be made for current and, lacking observational data, an estimate may be based on the following general information:

(*a*) Observations have demonstrated that a persistent wind will set up a wind-driven current with a velocity approximately 2 percent of that of the wind. This ratio can be expected to hold both in coastal areas and in the open ocean.

(*b*) The direction of a wind-driven current in the Northern Hemisphere has been found to be generally about 20° to the right of the wind in coastal areas, but theoretically this deflection is probably nearer 40° to the right of the wind in the open ocean. The rule for coastal wind-driven currents is not always applicable, especially when near the shore where the direction of the current depends on the angle between the wind direction and the coastline.

### *3376. A Dead-Reckoning Line*

In running a dead-reckoning line, certain precautions must be observed and certain data must be obtained. These involve (*a*) the initial position, (*b*) the terminal position, and (*c*) intermediate data.

*a. The initial position.*—An initial position for a dead-reckoning line should be selected which is correct beyond doubt. If data complete enough to fix positions are obtained farther offshore, but about whose reliability there is some doubt, they should be used merely as intermediate data to assist in the final adjustment of the dead-reckoning loop, but the line resulting from the first adjustment of the dead reckoning should not be moved far from its natural position in order to utilize such data.

When practicable, each dead-reckoning line should start from a series of fixed positions, a constant course and speed being maintained during the several positions, in order that these positions may establish the course made good and a log factor for the initial part of the line.

*b. The terminal position.*—As the dead-reckoning line approaches its end, a position must be fixed by conventional means as soon as practicable. If the offshore control is by R.A.R., an attempt should be made to get bomb returns even before these may be expected to give results. A single bomb return will provide a distance arc which may be used in adjusting the dead reckoning.

When the terminal position is to be a visual fix, especially if observed to buoys, it is essential that the most experienced officer available be on the lookout for the signals to come into view as the survey ship nears the control. The observation of a visual fix while the signals are still extremely distant or indistinct and when their whereabouts is unknown, is one of the most difficult phases of hydrography. Usually an experienced officer can locate two of the objects and set a sextant on the angle between them, passing the sextant to another observer who can maintain that angle, while the more experienced one finds the other object. The end of the line, like the beginning, should be fixed by a series of reliable fixed positions, and they and the more doubtful data should be utilized in the adjustment as described for the initial position.

*c. Intermediate data.*—Between the initial and the terminal positions all control data such as single bomb distances, angles, and bearings must be observed and recorded, in addition to the dead-reckoning data, for use in the final adjustment of the loop. When the adjustment is made, some of these data will be found to be either in

error or less accurate than the dead reckoning and there should be no hesitancy in rejecting them when they are found to be so.

### *3377. The Dead-Reckoning Abstract*

A dead-reckoning abstract on Form 722, R.A.R. and Dead-Reckoning Abstract, should be kept as the dead-reckoning line is run. On this abstract all control data should be entered which are to be used in plotting and adjusting the dead-reckoning line and also the courses and the distances made good insofar as can be estimated. Each officer on the bridge has his own duties in connection with obtaining, recording, and plotting these data. If there is a considerable lapse of time between the running of dead-reckoning loops, the plotting and adjustment of a loop may be performed at any convenient time after the run has been made. If, however, one dead-reckoning loop is run immediately following another, it is essential that the plotting and adjusting be kept up to date. Usually the dead reckoning can be plotted as it proceeds and a completed loop can be adjusted while the next loop is being run.

### *3378. Adjustment of Dead Reckoning*

The dead reckoning should be corrected for all known factors affecting course and distance before it is plotted, so that it represents the actual track of the vessel as accurately as possible before adjustment to the terminal position. The amount and direction by which the terminal position plotted by the dead reckoning fails to check the terminal position determined by fix is the *dead-reckoning closure.* This dead-reckoning closure is usually first proportioned *by time* throughout the entire run, in the same way that a traverse closure in ground surveying is proportioned throughout a traverse according to distance.

The above is usually only the first step in the adjustment of a dead-reckoning loop; there are other control data which must be taken into account before the adjustment can be considered complete. The courses as determined by the several fixed positions at the beginning of the line and by the several fixed positions at the end of the line must be given weight at the beginning and end of the dead-reckoning loop. The effect of this is that the first and the last portions of the dead reckoning must frequently be plotted as flat curves rather than straight lines. Other intermediate data such as single bomb distances, loci of single angles, and bearings, are plotted and each is analyzed with reference to the preliminary adjusted dead reckoning. Those partial data which appear reasonably correct and probably stronger than the dead reckoning itself are accepted and the dead reckoning is readjusted to make it conform to them. (See also **764** and fig. 161.)

### *3379. Precise Dead Reckoning*

Precise Dead Reckoning was the name given to a type of accurate dead reckoning used before the advent of echo sounding in depths where the survey ship could be anchored. The ship ran at reduced speed in order to obtain the soundings. The most notable characteristic of this type of dead reckoning was that the ship was anchored for current observations at the beginning and end of each sounding line and at intervals of about 2 hours on the line. This method was described in Special Publication No. 73, Precise Dead Reckoning in Offshore Soundings.

Still later, additional accuracy was gained by anchoring lines of buoys perpendicular to the coast, spacing the buoys about 10 miles apart along the lines and the parallel lines of buoys about 10 miles from each other. The buoys were located by full speed double runs to obtain accurate log distances and dead reckoning. The sounding lines were then run at reduced speed parallel to the

lines of buoys and were controlled by bearings taken at 10-minute intervals on the buoys visible. The bearings were plotted and the dead reckoning was adjusted to the bearings.

Neither of the above methods is now used and they should be considered obsolete.

## 338. Astronomic Sights

Hydrographic surveys beyond the limit of visibility of terrestrial objects and survey buoys or beyond the range of R.A.R. shall be controlled by dead reckoning and astronomic observations.

In general, where the sounding line is beyond the range of control stations for more than 8 hours, it shall be planned so as to be controlled by astronomic sights, weather permitting.

At least one and preferably several positions at both the beginning and end of a sounding line controlled by astronomic observations must be well fixed from the offshore control, which may be shore objects, survey buoys, or R.A.R. stations. The beginning and end of the line should be fixed as required in **3376**.

Astronomic sights are used in hydrographic surveying in a manner similar to their use in navigation, except that the sights are taken with greater precision and care, and they are used more accurately to control the sounding line. It is not the intent to explain fully in this Manual all details of observation, computation, and use of astronomic sights as these are usually well known and are adequately explained in any good epitome on navigation, such as Bowditch. The information in this Manual is limited to refinements of observation and the best methods of using the observational data to control hydrography.

### *3381. The Use of Logs*

At least two well-rated logs should be in operation at all times that sounding lines are controlled by astronomic sights. The log factors of these must be accurately known; the method of determining these log factors is described in **4454**. The use of the logs is similar to their use in dead reckoning which is described in **3374**. On long lines controlled by astronomic sights logs should be read at 10-minute intervals or oftener, and each log reading recorded as a fix. (See also **4453**.)

The log reading at each astronomic sight must be determined to correlate the latter with the depth measurements. When the astronomic sight consists of a series of several (generally six) observations on one celestial body, the log may be read at the midpoint of the series of observations. This is generally not as satisfactory as a subsequent computation to determine the log reading at the time of the sight. Unless the series consists of an odd number of observations, the midpoint will come between two observations, and even when the series consists of an odd number, the mean time of the series will not correspond exactly with the time of observation of the middle sight. The ship's time which is used to record the log readings is kept so nearly correct that for all practical purposes it may be assumed to represent Mean Time. After a sight has been computed, the Greenwich Civil Time of observation may be used in conjunction with the times of the log readings before and after a sight to determine the log reading at the sight by interpolation.

At morning and evening star sights the several lines of position are run forward or backward to a selected central time for which a position is determined. At these observations the log reading for each sight must be computed as described above from the series of regular 10-minute log readings extending over the time during which all of the sights were taken. It is convenient to select a central time for the series which is a regular 10-minute position.

The log reading for each sight should be entered in the appropriate space on Form 719, Astronomic Sight for Hydrographic Control, and on Form 722, R.A.R. and Dead-Reckoning Abstract.

### *3382. Computations*

Form 719, Astronomic Sight for Hydrographic Control, has been arranged so that any kind of astronomic sight may be computed on it. It is arranged for the use of the Marc Saint Hilaire method using the cosine-haversine formula. Its use is not obligatory if observers prefer other methods of computation which will give equally correct results. For a series of morning or evening star sights which can be computed from the same dead-reckoning position there is considerable advantage in using the Marc Saint Hilaire method. For single observations this method is longer than some of the newer methods which eliminate the necessity for the use of logarithms.

Azimuths of observed celestial bodies can be scaled graphically to the nearest one-fourth degree from Captain Weir's Azimuth Diagram. Considerable time is saved by the use of the graphic method, especially if a number of azimuths are to be scaled at the same time, and the results are as accurate as warranted. The declinations of a number of stars used most frequently can be plotted on the diagram. It contains complete instructions for its use. Azimuths can also be found from computed tables, such as H. O. No. 214, Tables of Computed Altitudes and Azimuths.

If other methods of computation are used the observed and dead-reckoning data for which spaces are provided at the top of Form 719 should be arranged in the same general way on the adopted form. All computations should be worked to the nearest 0.1 second of time and to at least the nearest 0.1 minute of arc.

The original computations should be bound together with the sheets on which the lines of position are plotted and with the dead-reckoning abstracts (Form 722) when forwarded to the Washington Office with the other survey records. Smooth copies need not be made of either the computations or the plotted lines of position. (See **8313**.)

### *3383. Lines of Position*

An observation on one celestial body gives a line of position passing through the observer's position at right angles to the azimuth of the celestial body. One observation does *not* give a fix.

Each sun sight observed during the day should be plotted and used as a line of position to which the dead reckoning is adjusted. At the time the line is being run, one sun sight may be *run up* to another in order to determine the ship's probable position at the moment, and whether or not a change in course is needed in order to follow the proposed line. When the final adjustment of the sounding line is made on the smooth sheet, sun sights shall not be run up, but must be used as separate lines of position at the times of observation to which the line as a whole is adjusted.

In adjusting the dead reckoning to separate lines of position the first step is to make a preliminary adjustment of the line to those lines of position which most nearly parallel it and those which are most nearly at right angles to it. The former serve to place the line in azimuth and the latter to determine a log factor for the interval. For example, if the true direction of the line is east or west, morning and afternoon sun sights taken when the sun is on the prime vertical will cross the line at right angles. From the log distance between these and the corresponding scaled distance between the lines of position a log factor for this interval can be derived. Without disturbing it in azimuth, the line may then be moved north or south until it coincides with the

noon line of position. Further adjustments may be required when the intermediate lines of position are considered. In some circumstances the procedure should be reversed and the position of the line made to agree with the noon sight first, the log factor being determined afterward. The above example is oversimplified because sounding lines are rarely run exactly east or west and morning and afternoon sun sights are rarely obtained when the sun is exactly on the prime vertical. It will serve, however, to explain the method which, of course, has to be modified to meet each individual case.

Where the direction of the line is such that it is neither parallel nor perpendicular to lines of position which can be used as described above, the preliminary log factor to be used during the day must be determined from the interval between the fixes obtained at morning and evening star sights. Otherwise the line must be adjusted by a trial-and-error method, trying various log factors and positions of the line until its most probable relation to the lines of position has been determined.

### *3384. Accuracy of Astronomic Observations*

Astronomic observations should be made with navigating sextants, read to the nearest 10 seconds, and the time of each observation marked to the nearest fifth of a second. When only one person is observing at a time, the times of the observations may be marked by the recorder on the chronometer, if it is conveniently located. When two or more observers are engaged simultaneously in taking star sights, it is impracticable to use the chronometer for all observations. In such cases and when the chronometer is not accessible, best results are obtained by the use of a stop watch which should be compared with the chronometer immediately before and after a series of observations. For stellar observations each observer should have his own recorder and stop watch.

In astronomic observations a change of 1 minute in altitude moves the line of position 1 nautical mile, a fact which should always be borne in mind. An observational error of 15 seconds in altitude will make an error of one-fourth nautical mile in the line of position.

At the Equator the altitude of a celestial body on the prime vertical changes 1 minute of arc in 4 seconds of time. Therefore, if the time of observation is 1 second in error, the resulting line of position will be in error one-fourth of a nautical mile. For other latitudes and other azimuths the error in position caused by an error in time is correspondingly less, varying with the cosine of the latitude and the sine of the azimuth measured from the pole. This is represented by the following formula:

$$\text{Position error (in nautical miles)} = \frac{t}{4} \cos \phi \sin \alpha$$

in which $t$ is the time in seconds, $\phi$ is the latitude of the observer, and $\alpha$ is the azimuth of the observed body east or west of the elevated pole of the observer.

It is probable that a careful observation on one star, made under the best conditions with an accurate sextant in good adjustment, can be counted on to give a line of position correct within one-half mile. And, in general, the accuracy of an individual sun sight observed under similarly good conditions is somewhat greater.

A series of star sights which was analyzed in 1930 had an average intercept of 0.93 nautical mile. These sights were made by several observers; unreliable sights were rejected from the average; the sights were observed from a vessel at anchor; but some of the other conditions were not the best. The results showed practically no personal error.

A series of 18 sets of star sights by 3 observers was analyzed in a different way. There were four or more star sights in each set. All were observed from the vessel at anchor. The probable error of the resulting position was 0.07 nautical mile and the probable error of the position determined by any one set was 0.29 nautical mile. It is to be noted that the systematic error in longitude discussed in **3384B** is not accounted for in this determination of probable errors.

### A. ERRORS OF OBSERVATIONS

There are certain errors in astronomic sights that are constant or symmetrical, or nearly so, and which will affect all observations of a series alike. These are partly eliminated by the method prescribed for a series of morning or evening star sights (see **3387A**). Among these are index, refraction, and personal equation errors. A small error in the index correction or an incorrect determination of the height of eye affects each line of position an equal amount and only alters the size of the figure of error formed by the plotted lines of position, provided a proper selection of celestial bodies has been made. The same is partly true of refraction if it is of abnormal amount in all directions. Systematic personal equation errors likewise are more or less canceled out. A good sextant with an accurately graduated arc should always be used for astronomic observations, but systematic errors of graduation or errors caused by sextant mirrors will be largely compensatory when celestial bodies of nearly the same altitude are used. Errors due to nonverticality of the sextant, likewise, will more or less cancel out when bodies of approximately the same altitude are observed.

Accidental errors of observation, however, are not eliminated by observing a series of stars symmetrically arranged, and only observations made by experienced officers who are able to obtain rapid and consistently good results should be used. Inexperienced officers should be given every opportunity to take and compute sights for practice, but their results should not be used officially until they are known to be trustworthy.

Regardless of the fact that an error in the index correction or height of eye is eliminated by observations on stars symmetrically arranged, both should always be carefully measured because the observation of stars in all directions may be prevented. In addition to the errors which may exist in an individual star sight, another kind of error may exist in a sun sight. This is the error caused by imperfect shade glasses, described in **4515**(*c*) to which reference should be made.

It must be recognized then that a position determined from a series of stellar observations taken under the best conditions is likely to be far more accurate than a position on a line adjusted to individual sun sights observed under the best conditions during the day.

### B. ERROR IN LONGITUDE

All other conditions being equal, there is likely to be a greater error in an astronomic sight on a celestial body in an east or west direction than on one in the north or south. The reason for this is twofold: An error in time will affect the line of position proportionately more, the more nearly the body bears east or west; and celestial bodies change proportionately faster in altitude, the more nearly they bear east and west, making accurate observations more difficult.

The effect of an error in time on a line of position is discussed in **3384**; there may be an error in the chronometer time, in the watch time, or the recorder may have a personal error.

Owing to the more rapid rate of change in altitude, the vertical angles measured on east and west celestial bodies are less accurate than those on north and south ones. Observers are likely to have a personal error, so that they always mark a little late or a little early. This seems to be more pronounced for stars at greater altitudes and when the vessel is rolling, and is probably due to the rotary motion customarily given to the sextant in attempting to make certain that the observation is marked when the sextant is in a vertical plane.

The effect of an error in time or a personal lag in observation is to translate all lines of position east or west of their true positions by an equal amount. Such an error is *not* eliminated by a series of star sights selected to plot in a symmetrical figure (see **3387**A).

Experience has shown that positions derived from star sights taken by several observers and worked up independently almost invariably differ more in longitude than in latitude, and that the difference between any two observers is likely to be consistently of about the same magnitude and in the same direction.

### C. THE IMPORTANCE OF A DISTINCT HORIZON

A distinct and clear horizon is probably the most essential of all requirements for obtaining accuracy in astronomic observations. Only in very clear and calm weather is the horizon perfectly distinct and sharp. In stormy weather when the height of the seas makes the horizon noticeably irregular, better results may be obtained by taking the observations from as high a station as practicable in order to increase the distance to the horizon. In weather which is not perfectly clear, dark clouds low on the horizon often render it indistinct and at times sizeable errors have been made in observations by mistaking the upper edge of a low narrow band of cloud or fog for the actual horizon. In hazy weather, or when the horizon is indistinct, observations from a low elevation will give better results.

The brightness of the horizon is a most essential requirement in stellar observations. For this reason it is extremely important that evening stars be taken as early and morning stars as late as practicable, when there is sufficient daylight to illuminate the horizon reasonably well. There is a period of 15 to 40 minutes, varying with the latitude, during morning and evening twilight which is best for stellar observations. In extremely low latitudes rapid observing is necessary to get the required number of observations in the limited time available. The use of predicted altitudes and azimuths of selected stars will assist greatly in getting the evening observations while the horizon is still sufficiently bright (see **3387**B).

### D. OBSERVING PRECAUTIONS

For best results certain precautions should be taken in observing astronomic sights, which will give additional accuracy. The observer is stationed on a vessel, which is pitching and rolling more or less at all times. This disturbs the observer and continually varies the height of eye. To eliminate the effect of this as much as practicable an observer should station himself near the centerline and amidships. When the vessel is pitching or rolling, each observation of a series should be marked at a moment when the effect is at a minimum and the vessel is on an even keel.

Astronomic sights should not be observed from a station where the line of sight passes through or near the rigging, or near the masts, smokestack, etc., because the

observer's sense of verticality is impaired by the vision of nonvertical parts of the vessel.

A sight should not be observed through the smoke or heat from the smokestack because of the abnormal refraction created by the heat waves.

A brisk breeze blowing in the observer's eyes is very disturbing, and when he has to face the wind, every effort should be made to find shelter behind a wind deflector, mast, or other part of the ship, where the celestial body can still be observed.

No attempt should be made to take the individual measurements of a set of observations at regular intervals. Better results are obtained by marking each when the observer feels that it can be measured most accurately, regardless of the irregularity of the intervals between successive sights.

### E. RATING OBSERVATIONS

At the time of observing and not later, each observer should rate each set of sights, according to his opinion, "excellent," "good," "fair," or "poor," the rating being entered in the space provided on Form 719. This is a relative rating and is used later in giving weight to each line of position when determining the probable position. It does not matter if one observer's rating is "good," while another observer's rating of the same star taken at the same time is only "fair." In rating sights the following factors should be considered:

(1) The relative distinctness of the horizon below each star observed.
(2) The disturbing effect of the roll and pitch of the vessel and its effect on the height of eye.
(3) The direction of the wind and whether or not it is blowing into the observer's eyes.
(4) The rate of change in altitude of the star.
(5) The relative distinctness of stars of different magnitudes.

The observations may also be rated by using the altitude rate-of-change table, as described in **3385**. The use of these ratings in determining the probable position is discussed in **3387**.

### *3385. Altitude Rate-of-Change Table*

In a given latitude, the rate of change of altitude of any celestial body is constant for a given azimuth. This fact may be utilized to compute tables or construct graphs from which the rate of change in altitude per minute or per second may be determined for any observation.

The accuracy of sextant observations at sea depends on a number of variable factors, some of which are practically indeterminate. Some of these are the effect of the pitch and roll of the vessel, the effect of a breeze blowing in an observer's eyes, the rapidity of change in altitude of the observed body, the distinctness of the horizon, and the experience of the observer.

The accuracy of a series of observations on the same celestial body may be tested by the altitude rate-of-change table. If the differences between successive observed altitudes are compared with the mathematically correct differences in altitude for equal intervals of time, the discrepancies between the observed and the true values are an index of the accuracy of the observations.

The data for the tables, or from which the graphs may be constructed, are found by means of either of the following formulas:

$$\text{Change in altitude} = 15 \cos \phi \sin \alpha$$

in which $\phi$=latitude and $\alpha$=azimuth of body from the pole, and the resultant change in altitude is in minutes of arc per minute of time, or seconds of arc per second of time; or

$$X=4 \sec \phi \cos \alpha$$

in which $X$ = the number of minutes of time corresponding to 1° change in altitude, or similarly, the number of seconds of time for 1 minute change in altitude; $\phi$ and $\alpha$ being as above.

A table prepared for each 5° azimuth and for two or three selected latitudes will be found satisfactory. The table may be entered by interpolation, or a graph for each latitude may be constructed with the azimuth for one argument and time for the other argument.

The difference between any two consecutive observations of a series should rarely differ from the computed value by more than 15 seconds of arc.

The altitude rate-of-change table may be used to weight observations, for it is obvious that the more adverse most of the conditions of observation are, the greater will be the discrepancies between the observed and the computed differences. In addition to serving as a means of judging the relative quality of the observations, the use of the rate-of-change table will detect small accidental errors in the recorded times or the readings of the sextant.

### *3386. Sun Sights*

When the sun is visible, observations should be made on it at least five different times during the day. The early morning and late afternoon sights should be taken preferably when the altitude of the sun is between 12° and 25°. The noon sight should be taken at local apparent noon and the mid-morning and mid-afternoon sights should be taken at times approximately halfway between the noon sight and the early morning and late afternoon sights.

The meridian altitude sight at noon should be taken independently by at least three observers. Sights at the other four times should be taken independently by at least two observers although, of course, not necessarily at the same times.

It is only when clear skies are prevalent that the sun sights can always be taken near the times desired. In stormy and overcast weather sights may be impossible, but in partly cloudy weather the observers must be on the watch to take advantage of the sun's momentary appearance through a break in the clouds in order to obtain the sight as nearly as practicable at the time desired. The quality of the observation is probably more important than the time at which it is taken, and if a poor or only fair sight is obtained near the time desired but conditions are better some little time later, the sight should be repeated and the first observation rejected.

The most valuable lines of position are those resulting from observations when the sun is on the prime vertical and the meridian. In certain latitudes and at certain seasons the sun is never on the prime vertical and at other times its altitude when near this azimuth is not appropriate for a sight. It is considered more important to observe the five sights at the times of day and altitudes prescribed above than it is to try to obtain sights when the sun is on the prime vertical.

### *3387. Position From Star Sights*

Each observer's morning and evening star sights shall be used independently to determine a probable position of the ship, after which the results should be compared and weighted if necessary and an official ship's position adopted. The star sights of one observer should never be combined with those of others in determining positions.

For accurate determinations, observations taken by different observers, by different sextants, or at different times of the day, should never be combined to determine a probable position.

When morning and evening star sights are taken from a vessel underway, the various sights of each observer must be *run up* or *run back* by dead reckoning to a selected central position.

Each observer's sights should be plotted on a separate sheet and a ship's position derived therefrom. Ordinary cross-section paper may be used for this purpose but polar coordinate paper is preferable. An arbitrary scale may be adopted which should be noted on each sheet used. A large enough scale should be chosen so that 1 nautical mile will be represented on the paper by at least 1 inch. In addition to the line of position, the dead-reckoning position for which the sights were computed, the run-up or run-back of each sight and the derived ship's position should be clearly indicated. The rough copies on which the lines of position were originally plotted shall be transmitted to the Washington Office; smooth copies are not necessary. The dead-reckoning position, the adopted position of the ship, and the lines of position after being run up or run back should be inked. The name of each star observed and its direction should be indicated alongside each line of position. The observed lines of position and the distance and direction each was run up should be left in pencil.

Due to the inherent inaccuracy of astronomic sights, the lines of position corrected for the run of the ship between sights will practically never intersect at a point. Three lines of position will form a triangle of error. The probable position of the ship derived from a series of morning or evening star sights is based on the assumption that there is some type of error common to all the sights, approximately equal in amount and in the same direction with reference to the stars observed. It is not especially necessary that the amount of this error be small, but for best results it must be symmetrical. In determining the most probable position of the ship the directions of the observed bodies must always be considered. For unweighted observations the probable position should be equidistant from the lines of position and should lie either toward or away from each star of the series; never away from some and toward others.

There are two general methods which may be used to find the most probable position, and in a series of more than three or four sights a combination of these is preferable. The first method is to move all of the lines of position either away from or toward the objects observed by an equal distance to bring them as nearly as possible to a common intersection (see *A* and *C* in fig. 58). In practice, it is not necessary to move the lines of position. The probable position may be found with the use of dividers, merely visualizing the transfer of the lines of position, but in this operation one must be certain to adopt a position which is on the correct side of each line of position considered; that is, it must be either toward or away from each star of the series.

The second method is to draw bisectrices between intersecting lines of position. Each bisectrix must be drawn so that it is either toward or away from the two objects observed. In a triangle of error formed by three lines of position the three bisectrices will intersect at a point, as in *B*, figure 58. For four lines of position from stars in four directions two bisectrices should be drawn, each between two opposite lines of position, as in *D*, figure 58. Where two opposite lines of position are from stars in the same direction, a mean line should first be drawn between them and this mean line and the other two lines treated as three lines and the bisectrices drawn as in *B*, figure 58.

When more than four stars are observed in one series, the lines of position in the same general direction should be combined to reduce the data to not more than four lines of position. Assuming all observations to be of equal weight, the lines of position from two stars in the same general direction should be combined by drawing the bisectrix between them. From the figure of error thus formed the most probable position is determined as described above. (See *E*, fig. 58.)

Other things being equal, observations on north and south stars are likely to be more accurate than those on east and west stars, because of the more rapid rate of change in altitude of the latter (see **3384**B). For this reason if more than four stars are observed it is preferable to combine lines of position to a resultant rectangular figure of error whose sides are roughly north-south and east-west.

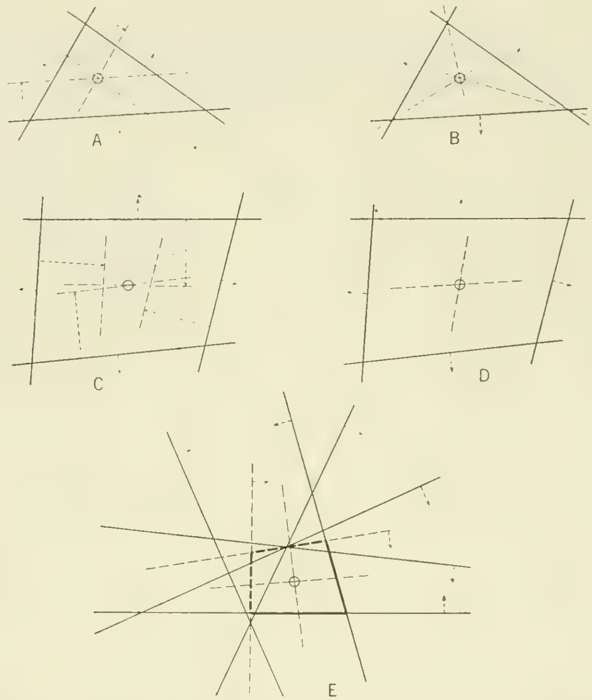


FIGURE 58.—Probable position of ship from stellar observations: *A* and *C*—by moving lines of position away from or toward the observed bodies by equal amounts. *B* and *D*—by the bisectrix method. *E*—by the bisectrix method when there are more than four observations.

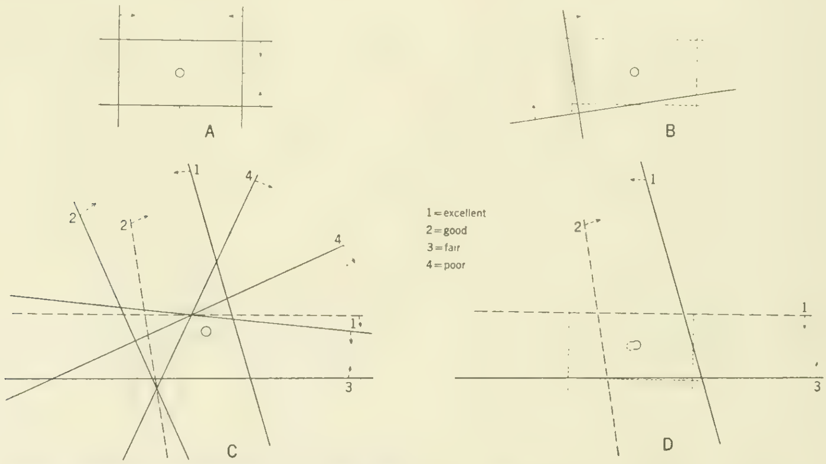


FIGURE 59.—Position from star sights, using a known figure of error. *A*. Characteristic figure of error from past experience. *B*. Characteristic figure of error used to determine most probable position from only two star sights. *C*. Position if lines of position in opposite directions are weighted without taking into consideration characteristic figure of error. *D*. Position from same lines of position as in *C*, but taking into consideration the characteristic figure of error. Note that the position is actually nearer the *good* west line of position than the *excellent* east one, and that it is almost equidistant from the north and south lines, although one is excellent and one only fair.

Repeated observations will disclose that each observer has a figure of error of characteristic shape and size, which is usually longer in one direction than in the other. This characteristic figure of error, once it has been determined for an observer, may be applied to one or two lines of position to derive a more probable position than would be otherwise possible (see *A* and *B*, fig. 59).

Not all of the observations in any one series are of equal weight. They should be weighted according to the rates given as described in **3384E**, and these weights taken into consideration in determining the most probable position. The treatment of weighted observations on stars in the same general direction is comparatively easy when they are combined by bisectrices to form one line of position.

The use to be made of weighted observations in opposite directions is a matter of considerable judgment. If the observation on a north star is "excellent" and that on a south star is "poor," it is not necessarily a foregone conclusion that the most probable position is close to the line of position derived from the observation on the north star. In using weighted observations on stars in opposite directions, the characteristic figure of error of the observer must be taken into consideration. If the average size of this figure is 1 mile between the north and south lines of position, this same approximate distance should be expected whether the observations are of equal or unequal weight. (See *C* and *D*, fig. 59.)

The weights of the different observations may be indicated on the plot by using a different colored ink for lines of position of different weights, or by writing the actual weight alongside each line of position.

### A. SELECTION OF STARS

To compensate for certain errors and to obtain maximum accuracy, the celestial bodies to be observed should be selected so that the lines of position will plot in a symmetrical quadrilateral. For best results the celestial bodies should be of about the same magnitude, differ by about 90° in azimuth, and be at approximately the same altitude. Theoretically, four stars should be selected approximately at the four intercardinal points, for their lines of position will plot in a rectangle and their altitudes will change at approximately the same rate. Such selection is seldom made in practice because most observers want to use Polaris as one of the stars and the others are selected with reference to it, with the result that the sides of the figure formed by the plotted lines of position are roughly north-south and east-west.

It is important that stars of approximately equal magnitude be selected in order to equalize as nearly as practicable the observing conditions on all observations of a series. If a bright star is observed in a series with several fainter stars, the observations on the former may be more accurate but the result will be an unequal distribution of error when the mean position is determined (see **3384E**). For the same reason neither a moon sight nor a sun sight should be combined with star sights; an additional reason is a different refraction if the altitude of the sun or moon is higher than that of the stars. An additional error may be introduced in the case of the sun by the use of a colored shade glass.

The altitudes of the observed bodies must be kept within certain definite limits. Bodies at comparatively high altitudes are undesirable because of the difficulty of measuring the altitude in a truly vertical plane. Bodies at comparatively low altitudes are usually invisible when the horizon is bright enough for best observations and low altitude observations are subject to greater errors of refraction. The best results are usually obtained from observations on bodies at altitudes between 15° and 20°, but

altitudes between 10° and 35° may be considered satisfactory. The lower limit may be reduced in tropic latitudes, for good results have been obtained there with altitudes as low as 5°. In higher latitudes the lower limit may have to be increased if there is abnormal refraction.

The group of celestial bodies selected need not be the same for all observers but no advantage is gained in using different ones. The tendency, at least in the evening, is for one observer to observe stars which have already been found by some other observer.

When observations on bright stars or planets have to be combined with those on faint stars, comparable conditions may be approximated by observing the bright stars first, as soon as they become visible in the telescope in the evening. In the morning the sequence should be reversed, the faint stars being observed first and the bright ones later when they have dimmed somewhat. Observations should not be made when the horizon is indistinct, but better results can be obtained under such conditions by using a sextant equipped with a binocular telescope. Observations should never be made at night, using a moonlit horizon, because of the likelihood of a false horizon.

### B. STAR IDENTIFICATION

An observer experienced in taking stellar observations should have no difficulty in identifying the principal stars in the heavens on a clear night, but an observer who has never taken such observations or who does so only at infrequent intervals must have some method of identifying the stars which he observes. Even one familiar with the heavens occasionally takes an observation on a star which he cannot identify, this occurring most frequently when most of the heavens is obscured by clouds and there is an insufficient pattern of stars visible in the vicinity of the one observed to make identification certain.

As a matter of routine, beginners should always note the approximate azimuth of each observed star, and experienced observers should note the azimuths of any observed stars whose identification is doubtful. Observed stars may be identified visually, graphically, or by computation. H. O. Chart No. 2100 may be used for visual identification. The pattern of the stars in any constellation or any section of the heavens compared with the same area on the star chart will disclose in most cases the identity of the star observed. Unfortunately, this chart includes only the brighter stars and a few of the fainter ones which form the patterns of the various constellations.

Stars may be identified by computation, using H. O. Publication No. 127, Star Identification Tables, or the star identification table following each degree of latitude in H. O. Publication No. 214, Tables of Computed Altitude and Azimuth. Entering the tables with the observed altitude and azimuth of the celestial body, its hour angle and declination may be found. Interpolation by inspection will suffice. The hour angle is converted into right ascension, and with the declination and right ascension the body may be identified in the Nautical Almanac.

If no tables are available the right ascension and declination of an unidentified star can be computed by the formulas and methods given on page 187, Bowditch, 1938 edition, under the heading "Star Identification."

The brighter stars may be identified by the use of the Rude Star Finder and Identifier, H. O. No. 2102*a* or H. O. No. 2102*b*. The latter is based on the same principle as 2102*a* but the star chart and the templates are on a smaller scale and the results cannot be obtained as accurately as from 2102*a*.

Star finders and identifiers serve another purpose besides identification. At morning sights any star to be observed is readily visible and its altitude may be measured and followed while waiting for the horizon to brighten sufficiently to take the observation. At evening sights the best results are obtained while the sky is so bright that the stars are difficult to find unless their approximate altitudes and azimuths are known. If certain stars are selected for observation in advance, their approximate altitudes and azimuths may be determined by the use of the star finders for given times of observations. A table may be made of the stars expected to be observed, listing the predicted altitudes of each at 2- or 3-minute intervals throughout the period when each star will probably be observed. From this table the altitude of a star at any given instant may be found by interpolation and set on the sextant, and with the sextant pointed in the predicted direction the star should be found in the field of view.

For greatest precision the construction of a special star chart is recommended, if it is expected that a large number of stellar observations will be taken in one latitude during a long period of time. This should preferably be an aluminum-mounted sheet on which all stars brighter than about magnitude 4½ should be plotted according to right ascension and declination. The largest convenient scale should be used. To fit this chart, templates similar to those of the Rude Star Finder may be made by using the values from various nautical tables used to compute astronomic sights. For example, H. O. Publication Nos. 203 and 204, Sumner Line of Position, may be used. The required values may be plotted directly on the star chart, smooth curves drawn through them, and the results engraved on a celluloid template by tracing. Any one template will give correct values only for the latitude for which it is constructed, but for this latitude the altitude of any star should be predictable within at least 10 minutes of arc. For most projects not more than two templates should be required.

The center of the template should always be placed on the star chart at the latitude for which it was constructed. For other latitudes the predicted altitudes must be corrected for the difference between the latitude of observation and the latitude of the template. This correction is equal to the difference in minutes between the latitude of observation and the latitude of the template, multiplied by the cosine of the azimuth of the star measured in degrees from the elevated pole of the observer. This correction may be derived mathematically by using a table of natural cosines, as found in table 31 of Bowditch, and a slide rule. The values of the corrections for differences of 30 minutes or less may be found in the table entitled "Altitude Correction for D. R. Latitude" in the back of H. O. Publication No. 214. The proper sign to be used in applying the correction will be self-evident; where the latitude of observation is greater than the latitude of the template for a star north of the prime vertical, the correction is additive and for one south it is subtractive.

### C. DAYTIME OBSERVATIONS ON STARS AND PLANETS

Although the stars and planets can rarely be seen with the naked eye during daylight, the brighter ones can frequently be observed by making use of their precomputed altitudes and azimuths to find them in the sextant (see B above). The planet Jupiter can frequently be observed in the daytime on an azimuth that will make a line of position from it cross advantageously with one from a sun sight. The planet Venus, when near quadrature, can be observed during the day, and a line of position from it will often serve the same purpose. Even Polaris, whose magnitude is only 2.1, has been observed during the daytime. Lines of position obtained from daytime observations on stars and planets should be crossed with sun sights taken at the same approxi-

mate time in order to obtain a fixed position at the time of sight, when the lines of position intersect at angles greater than 45°. Otherwise they should be used as individual lines of position.

## 34. HYDROGRAPHIC OPERATIONS

### 341. Personnel and Their Duties

The personnel required for various survey units has been briefly outlined in **142**. The specific duties of the various personnel are described here, except for those personnel required only for the R.A.R. method of control, whose duties are described in **671**.

It is to be understood that the duties described under two different headings here may be performed by one person or by two persons, depending on conditions.

#### *3411. Supervision by the Chief of Party*

During the progress of the survey the Chief of Party is required to supervise closely the field work and to inspect frequently the boat sheets and Sounding Records. He shall assure himself, by personal inspection of the field operations when necessary, that all units in his party are carrying on such operations in accordance with the requirements contained in the various manuals and in the project instructions.

The Chief of Party should examine each boat sheet daily, if practicable, paying particular attention to the adequacy and completeness of the survey with special reference to the determination of least depths on shoals, the location of and data relative to rocks and dangers of all kinds, the least depths on and the extent of bars obstructing a fairway, and the development of all navigable channels. Each channel should be studied carefully from the soundings plotted on the boat sheet to ensure that the intensity of the soundings is sufficient to show the limits and navigable depth of the channel throughout its extent or to determine where additional hydrography is required.

From this daily examination of the boat sheet the Chief of Party should indicate to the hydrographer where additional lines, more intense development, or any other data are required. Sounding Records and other recorded data should be examined occasionally to make sure that they are being kept in accordance with the requirements of the Hydrographic Manual and are complete and satisfactory in all respects. Only a general examination of the Sounding Records is required, the hydrographer in immediate charge being specifically responsible for the day-to-day examination and for the approval of each day's recorded data (see **3246**).

When it is impracticable for the Chief of Party to examine the boat sheets daily because of the detached work of a unit, he should make his examination at as frequent intervals as practicable.

Any general instructions issued to the hydrographer by the Chief of Party should be written in the Sounding Record and signed by the Chief of Party.

The supervision by the Chief of Party during the season and a final inspection of the boat sheet when it has been completed must be in sufficient detail to ensure the final adequacy and completeness of the survey before the departure of the party from the working ground at the end of the season.

The Chief of Party need not sign the Sounding Records, but in his approval of the survey (see **7941** and **8437**) he shall include a statement as to the amount of personal supervision of the field work and as to the frequency with which he examined the boat

sheet. This approval shall serve as a general approval by the Chief of Party of the smooth sheet and all associated records which are forwarded as part of the survey data.

### *3412. Officer-in-Charge*

The officer-in-charge of each survey unit is in charge of all survey operations of that unit, issues all of the neeessary orders, and is responsible for the adequacy and accuracy of the results; he is also responsible for the safety of the vessel, the personnel, the equipment, and the care which is taken of the equipment.

Almost invariably the officer-in-charge plots the fixed positions on the boat sheet, issues the necessary orders to the helmsman, selects the objects to which the sextant angles are taken, and orders the intervals between successive positions and the intervals between soundings.

In most cases of three-point fix control the officer-in-charge observes one of the angles, preferably the left.

The officer-in-charge of a launch party, or a party where watches are not changed throughout the day, shall be responsible for the accuracy and adequacy of the data in the Sounding Record. He should train himself to hear subconsciously all soundings, angles, and other data which are called out and repeated, so as to know at all times the depths being obtained and whether the data being recorded are correct. At the end of each day's work he shall approve the record for that day over his signature.

For hydrography on a survey ship operated on a watch basis, where the officer-in-charge of the bridge is relieved during the day, he shall be responsible for that part of the recorded data which occurred during his watch and shall approve that part of the record over his signature at the end of the watch.

### *3413. Anglemen*

The anglemen observe the sextant angles for the fixed positions in three-point fix control. Usually the left angle is observed by the officer-in-charge. The right angle may be observed by the recorder but is most frequently observed by a junior officer. It is in this position that the junior officer acquires the knowledge and experience which permit him subsequently to serve as officer-in-charge. In addition to taking the right angle, the right angleman supervises the work of the recorder, keeping a constant check in order to ensure that all of the required data are recorded in the Sounding Record (see **818**). He also oversees the sounding operations and, when not otherwise engaged, keeps a lookout ahead when for any reason this is necessary. The special notes that should be entered in the "Remarks" column of the Sounding Record (see **815**) are frequently given to the recorder by the right angleman.

Two anglemen in addition to the officer-in-charge are generally required on a ship where the objects are distant or faint, or where survey buoys are used as control stations.

### *3414. The Recorder*

The recorder keeps the official written record and notes of the hydrographic survey in the Sounding Record. He records the depths as reported by the leadsman or the fathometer attendant, the sextant angles observed by the two anglemen, or other control data, and all dead-reckoning data, with the respective times of the various events. He also records all pertinent notes in the "Remarks" column (see **815**).

For more complete instructions as to the manner in which the Sounding Record shall be kept, see **811** to **816** inclusive.

After the regular intervals between soundings and between positions have been ordered by the officer-in-charge, the recorder is the one who sees to it that the soundings and positions are taken at the required intervals, so long as constant intervals are maintained. The recorder repeats aloud, for verification, all important data which are called out to him to be recorded. When a sounding is reported, which, by comparison with previous soundings, appears to be possibly in error, the recorder must make a special point of having the leadsman or the fathometer attendant verify the depth which he is recording, and must indicate that the recorded depth has been verified by making a checkmark alongside it. The recorder must call to the attention of the officer-in-charge any unusual circumstances, such as a sudden unexpected deepening or shoaling in the soundings.

It is the duty of the recorder, assisted by the leadsman, to verify the length and markings of the leadline against the standard each day before and after hydrography and to enter the results of the comparison in the Sounding Record (see **4622**). It is his duty to see that the data are obtained and recorded which are required for the various standard rubber stamps used at the beginning and end of each day's hydrography (see **813** and **816**).

### *3415. Fathometer Attendant*

When surveying in deep water, using an echo-sounding instrument, the duties of the fathometer attendant and the recorder may frequently be combined, especially where the bottom is comparatively even, the depths are easily obtained, and the interval between the soundings is not too short. Generally, however, the fathometer attendant should have no other duties and should be free to devote his whole attention to the instrument so that the depth of the water is observed at all times and there will be assurance that no shoals nor least depths go unnoticed. A fathometer attendant with no other duties must be provided at the following times, regardless of whether the echo-sounding instrument is visual or graphic recording: when surveying in shoal and moderate depths, where the submarine relief is irregular, when the instrument requires frequent adjustment for optimum results, when readings are difficult to obtain, and for all echo sounding in launches.

A regular sounding interval is ordered by the officer-in-charge. This is usually dictated by the scale of the survey and the speed of the vessel and finally by the number of soundings which can be shown legibly on the smooth sheet or which are required for an adequate representation of the bottom profile. Regardless of the regular interval, however, it is the duty of the fathometer attendant to note the shoalest and the deepest soundings, and in each case these shall be reported to the recorder and recorded if they differ by more than 5 percent of the depth from the general slope of the bottom between soundings at regular intervals (see **343**).

The fathometer attendant must be familiar with the adjustments of the echo-sounding instrument so that the best and most accurate results are obtained at all times. In case of operational difficulties with which he is incapable of coping, he should notify the officer-in-charge immediately.

Where echo sounding is used in a survey it is assumed that a profile has been sounded along each line and that the instrument has operated and the fathometer attendant has observed it continuously between recorded soundings. If for any reason the contrary is true, the fathometer attendant must notify the recorder and the proper entry must be made in the "Remarks" column of the Sounding Record.

### *3416. Leadsman*

In handlead sounding the leadsman *sounds* when directed to do so by the recorder, measures the depth of the water with the leadline, and keeps a lookout over the surrounding water for shoals, discolorations, or other objects which may be of interest to the officer-in-charge. The leadsman must be a responsible person who takes his duties seriously and is interested in the results obtained. When sounding from a launch or small boat, the leadsman has a better point of view from which to scan the surrounding waters than any of the other personnel, because of the elevation of his position. He should be the first to detect submerged rocks and shoals by sight. Even when the bottom is not visible the leadsman frequently knows in advance from the sinking of his lead that the water has shoaled, or deepened, even before he has obtained the sounding, and where this may indicate a possible danger to the survey vessel he should notify the officer-in-charge immediately.

The leadsman usually has an assistant to haul in the leadline after each sounding. When the leadsman is directed by the recorder to determine the characteristic of the bottom, the assistant arms the lead. The intervals at which this is done are directed by the officer-in-charge. Between the times when the lead is armed, the leadsman should observe, by feeling with the lead, the relative hardness or softness of the bottom, notifying the recorder when any change is detected, and especially any indication of rocky bottom. On a survey ship two leadsmen usually alternate at handlead sounding, relieving one another each hour, because a great effort is required to heave the lead as far as necessary and it should not be required of one man throughout a 4-hour watch. On a launch the coxswain and leadsman frequently alternate in heaving the lead, but if the leadsman's assistant is experienced, he may alternate with the leadsman at their respective duties.

### *3417. Coxswain*

The coxswain on a launch, or the helmsman on a ship, steers the vessel in accordance with orders issued by the officer-in-charge. Most sounding lines now are run by steering compass courses. The coxswain must repeat, for the purpose of verification, each order which is given him, and if the order given is for a change in course of a certain number of degrees, he should also report the course on which he steadies. In launch hydrography the coxswain also assists the officer-in-charge by keeping a lookout ahead when he can do so in addition to steering.

Most changes in course are ordered by the officer-in-charge immediately after a fixed position has been plotted and the position of the vessel is known with reference to the proposed line. The coxswain or helmsman should quickly learn how soon after a fixed position he may expect the order to change course and he should be listening for such an order at this time and always be alert to comply with it in the shortest possible time.

Ranges may be run in small-boat hydrography and in a small percentage of launch hydrography. A coxswain should be trained to keep the vessel on the range once it has been placed on the sounding line and headed in the correct direction, and he should be capable of selecting new objects as required for ranges on adjacent lines. (See **3142** and **3453**.)

## 342. The Operation of Sounding

There is no essential difference in the methods employed in sounding from a ship, launch, or small boat. Probably more than 99 percent of the soundings are now echo

soundings. The echo method has replaced the use of the wire and lead almost completely and is rapidly replacing the handlead. Vertical direct measurements by both handlead and wire are still required for purposes of comparison. The handlead is still most effective for *feeling* over shoals and is used on launches or small boats when no echo-sounding apparatus is available. The sounding machine and wire, except for. comparisons, are used mostly in obtaining temperatures and water and bottom samples.

### *3421. Handlead Sounding*

Handlead soundings are usually taken from a slowly moving vessel. They are practicable only in depths where the leadsman can heave the lead far enough ahead to obtain a vertical cast from a vessel proceeding at an economic speed. This depth limit will vary considerably, depending on the skill of the leadsman and the height of the sounding chair above the water. Under average conditions in small launches the limit will be approximately 10 fathoms and on ships and auxiliary vessels approximately 15 fathoms, although an exceptional leadsman can obtain soundings in depths of 20 fathoms. On ships and auxiliary vessels where the height of the sounding chair above the water is sufficient, the elevation and the stability permit the leadsman to throw the lead farther ahead than is practicable from lesser heights and from small launches and boats. The end of the leadline should always be made fast to the sounding chair.

To obtain a sounding the leadsman stationed in a sounding chair heaves the lead far enough ahead to give it time to sink to the bottom just before the leadsman is over that point. A right-handed leadsman coils in his left hand as much line as must be heaved out to obtain a vertical cast. He grasps the line at the toggle with his right hand and swings the lead over his head in a vertical arc for one or two complete circles to give the lead sufficient momentum, releasing it at the bottom of one of the swings so that it is cast ahead in the direction of progress. As the lead is thrown ahead he pays out the coiled line in his left hand. When the lead strikes the water it begins to sink vertically, but the speed of the vessel is often greater than the rate the lead sinks, so that the leadsman has to gather in the slack line as the vessel approaches the spot where the lead hit the water. If the proper amount of line has been thrown out the lead will have sunk to the bottom just before the vessel arrives over it. The leadsman then hauls the line taut and raises the lead slightly off the bottom to straighten the line and lead, lowering it again to touch the bottom just as the sounding chair comes vertically over the spot. Immediately after the depth has been measured the line is hauled in by an assistant, except in shallow depths, and coiled in readiness for the next sounding.

From a rolling launch or small boat where the sounding chair is only a few feet above the water, the leadsman generally cannot swing the lead over his head; otherwise the procedure is the same.

After a sounding has been obtained and the line is being hauled in, it trails aft along the side of the vessel. During this time the hydrographer must be careful in changing course not to risk fouling the leadline in the propeller. When a right-handed leadsman is sounding from the starboard sounding chair the course may be changed to the right with impunity, but changes of more than a few degrees to the left should be made with caution, until after the leadline has been hauled clear of the propeller.

The leadsman should be trained to gage the probable depth from the soundings immediately preceding in order to heave out just the right length of leadline. Too much may be just as objectionable as too little. When sudden changes of depth are expected by the hydrographer, the leadsman should be warned and given an estimate of the amount of shoaling or deepening (see **3234**).

When there are waves or swells the leadsman must be careful to allow for their height so that the reading of the leadline will give the depth from the mean water surface. The leadline should always be read at the surface of the water. To read the handlead at night from a ship, a floodlight should be installed where it can be directed on the water below the sounding chair. The depth should never be obtained by subtracting the estimated height above the water of a leadline mark in the leadsman's

FIGURE 60.—Handlead sounding from launch.

hand, or by subtracting the height of the deck of the sounding chair from the leadline reading at this point.

The rate at which the lead on a leadline sinks when thrown from a moving boat varies according to its weight, its shape, and the skill with which it is thrown. An idea of this rate may be gained from the fact that an ordinary 10-pound lead used in sounding will reach bottom in 6 fathoms about 5 seconds after it strikes the surface. The same 10-pound lead, dropped vertically from a stationary boat, will sink to the bottom in 6 fathoms in about 3 seconds.

Errors occur in leadline soundings when the leadline is not straight or the lead is not vertically below the leadsman when the depth is read. It is almost impossible to avoid a curve or underwater bight in the leadline when sounding in strong currents and there may be a similar error in soundings taken by inexperienced leadsmen in the absence of current (see **3464**).

With the wire-core tiller rope now used for leadlines there is less likelihood of an appreciable error in the length of the line than there used to be. However, each leadline used must be compared with standard marks before and after each day's sounding and the results noted in the Sounding Record (see **4622**). If errors are found in the length of the leadline the recorded soundings must be corrected for them when reduced (see **8221**).

### *3422. Wire Sounding*

To obtain a vertical wire sounding the ship or launch must be stopped while the wire is running out. In lesser depths the lead should not be released until the vessel is stationary in the water; in greater depths it may be released while the vessel has a slight headway. During the descent of the lead the vessel is maneuvered to keep the wire vertical until the lead strikes the bottom. In sounding from a launch, the launch proceeds ahead as soon as bottom has been reached and while the wire is being reeled in. In greater depths sounded from the ship the wire must be reeled in to within a few hundred fathoms of the surface before going ahead.

From a launch the wire should not be allowed to run out at a rate exceeding 100 fathoms per minute. From a ship it can be payed out at rates up to 150 fathoms per minute for about the first 1,500 fathoms, at rates not to exceed 100 fathoms per minute for the second 1,500 fathoms, and in greater depths at a rate not exceeding about 50 fathoms per minute. At rates faster than these there will be danger of the wire jumping off the reel during the descent or when the lead strikes the bottom. When sounding in rough weather these rates must be decreased. The wire should never be reeled in at a rate faster than 100 fathoms per minute.

Considerable skill and experience are required to operate the sounding machine, especially in letting the wire run out and in braking when the lead strikes bottom so that the wire will not jump off the reel and become entangled around the drum and shaft. For use in such accidents a stopper should always be kept available which can be attached to the wire to take the weight of the wire and lead while the snarled wire is being cleared. In extreme cases it is necessary to cut the wire to clear it, making a temporary splice in order to heave in the lead. When sounding in rocky bottom and in rough weather, particularly from a launch, it is almost inevitable that the wire will be parted occasionally and the lead lost. A supply of spare leads should always be kept on hand.

In great depths, and when the sea is rough, it is often difficult to detect when the lead strikes bottom. If the wire is allowed to continue to run out after the lead strikes bottom, the wire is likely to kink and may then part when it is reeled in.

On modern survey ships, sounding machines are installed on the bridge deck with the wire led outboard to a fair-lead at the end of a boom (see **4633**). When soundings are taken with such an installation the ship can maneuver at will to keep the sounding wire vertical. To obtain a deep sounding the ship should be hove-to, headed into the wind, with the wind slightly on the bow over which the sounding wire leads. This will ensure, if the ship falls off the wind, that the wire will not lead under the ship's bottom. With a twin-screw vessel no difficulty will be encountered in keeping the wire vertical. More skill is required with a single-screw vessel, but better results will be obtained by keeping the vessel heading nearly into the wind at all times.

In addition to leeway there will often be surface currents which will affect the position of the ship but will not influence the lead after it has descended a few hundred fathoms. In such cases the ship may have to steam ahead continuously into the current or wind to keep the wire vertical. If, in spite of the care which is taken, the wire leads

at an angle when the lead strikes bottom, the ship should be maneuvered to bring the wire vertical and the lead should be raised off the bottom to permit the wire to straighten out, being subsequently dropped again in order to measure the depth.

When taking vertical wire soundings the vessel must be stopped for each sounding and, in addition to the time of each sounding, the time interval run between soundings must be entered in the Sounding Record. The time at which the vessel starts ahead and the time at which it stops are recorded, but these times are not necessarily the times of the orders "to go ahead" and "to stop." The interval between them should equal the time which would have been required for the vessel to traverse the distance if it had been traveling at regular speed throughout the interval. The recorded time of going ahead should be the instant just before the vessel has attained a normal speed on course. The recorded time of stopping should be about midway between the time of the order to stop and the time the vessel is stationary in the water.

Errors in wire soundings occur from the lead not being vertically under the ship and the wire not being straight. As stated above, the ship should be maneuvered until the wire is *apparently* vertical before reading the depth. However, too much reliance cannot be placed on the accuracy of such soundings, for the verticality of the wire *below* the surface is unknown and in some cases uncertain.

### *3423. Echo Sounding*

In contrast with handlead and wire sounding, echo sounding is an indirect method of measuring the depths of the water. The soundings may be obtained while the vessel proceeds at full speed and, for the depths of which the apparatus is capable, the operation becomes principally one of navigation and position fixing. This method of obtaining soundings and the various instruments and their use are described in chapter 5.

## 343. Frequency of Soundings (Sounding Interval)

The interval between successive soundings along a line is determined by the officer-in-charge, and depends on the depth of the water, the nature of the bottom, and the method used to obtain the soundings. In general, sounding intervals should be uniform between consecutive positions, but a uniform interval should not be rigidly adhered to when soundings taken at irregular intervals will better define the bottom profile. For convenience in plotting, a sounding should be taken at each position and at regular intervals of time and distance between consecutive positions.

### *3431. Frequency of Leadline Soundings*

In an area of even bottom and regular slope, an interval between handlead soundings should be selected which will give the leadsman adequate time to obtain vertical soundings without undue haste in his operations. The distance between handlead soundings should never be so great as not to provide enough soundings according to **7724**. This distance interval may be altered by adjusting either the time interval between soundings or the speed of the vessel. Under normal conditions and at an appropriate sounding speed, the following time intervals will usually be found satisfactory for handlead soundings:

| | |
|---|---|
| Depths under 2 fathoms | 15-second interval |
| Depths from 2 to 4 fathoms | 20-second interval |
| Depths from 4 to 7 fathoms | 30-second interval |
| Depths from 7 to 10 fathoms | 40-second interval |
| Depths from 10 to 15 fathoms | 1-minute interval |

Shorter intervals are desirable to obtain a more accurate delineation of irregular submarine relief, as in channels or when crossing bars, reefs, and shoals. These intervals should be uniform between consecutive positions when practicable, but in depths of critical importance to navigation where the bottom is very irregular, the uniform intervals should be abandoned and soundings taken as rapidly as accurate vertical soundings can be obtained. When the uniform spacing is abandoned, the exact time at which each sounding is obtained must be noted in the Sounding Record.

### *3432. Frequency of Wire Soundings*

Intervals between vertical wire soundings, with the survey vessel stopped, should not exceed one-half the distance between sounding lines.

### *3433. Frequency of Echo Soundings*

In echo sounding, depths are measured continuously along each sounding line, but when the echo-sounding instrument is of the visual type, there is no permanent record of the profile except that provided by the recorded soundings in the Sounding Record. The fathometer attendant shall observe the depths registered on a visual instrument at all times and, except as provided in **3415**, shall have no other duties which will prevent this attention.

Where the depths are uniform or the slope is uniform, the maximum interval between recorded soundings shall be that which will provide soundings for the smooth sheet in accordance with **7724**. Wherever the depth varies more than 5 percent from the uniform slope between the soundings at regular intervals, additional intermediate soundings must be recorded at their exact times.

In areas of irregular submarine relief, too much importance must not be attached to the maintenance of a uniform interval. A uniform interval facilitates the plotting of the smooth sheet, but it is more important that the recorded soundings give a true representation of the irregularities of the profile. In such areas the least depths of all the irregularities must be recorded and between them the deepest depths, with as many intermediate soundings as are required to define the profile accurately. At least as many soundings must be recorded as can be shown on the smooth sheet (see **7724**). Particular care shall be exercised to obtain and record at their proper times all the critical soundings, such as the least depths on shoals or other elevations of the bottom, and the maximum depths between these features and in troughs and valleys. Soundings must also be recorded at each abrupt change of slope of the bottom.

When echo soundings are obtained with a graphic recorder, a permanent record of the profile is obtained, from which the soundings for the smooth sheet shall be scaled. For the immediate use of the hydrographer during his survey at least as many soundings must be plotted on the boat sheet as are required to determine the adequacy of the survey and the areas which need additional development. These soundings may be recorded in a temporary Sounding Record or taken from the fathogram, at the discretion of the hydrographer.

### *3434. Soundings at Wharves and in Docks*

Where there are wharves and docks within the area of a hydrographic survey, accurate sounding lines shall be run close to and along the outer faces of the wharves and

in the docks and slips. The lines and soundings should be referenced to the wharves and piers by measured distances using the method described in **3344**, or a substitute therefor which will give comparably accurate results. Extra precaution should be taken that all soundings are vertical, are measured by pole or an accurate handlead, that the tide is accurately known, and that the position of each sounding is accurately known with reference to the wharf. The sounding lines and the soundings along the lines shall be as close together as practicable for this type of survey.

In addition to any other lines which may be run, soundings shall be taken from the edges and faces of the piers and along the line likely to be occupied by the keels of vessels berthing there. These data in the vicinity of wharves and docks should be shown on subplans in accordance with **7751**, wherever the scale of the regular survey of the area is too small to show the data adequately.

## 344. The Operation of Position Fixing

Although the depth of the water at any specific place may be measured with considerable accuracy, this knowledge is valueless unless the geographic position of the measured depth is known, or its position is referenced to adjacent land features. The operation of determining the horizontal position of a sounding or depth measurement is known as *position fixing*. This is a procedure which must be repeated along the sounding line at sufficiently short intervals, depending on the scale and the spacing of the soundings and the lines.

When practicable, fixed positions should be obtained at regular intervals and each position should coincide with a sounding to facilitate spacing and locating the intermediate soundings. This is not an essential requirement, however, and in certain kinds of hydrography is disregarded. Irregular intervals may be necessary to comply with other requirements, and the difficulty of obtaining a position on a sounding may be greater than the inconvenience that is caused in the subsequent plotting of the soundings.

The actual operations of position fixing by various methods are described in section **33** and the frequency with which positions should be obtained for each type of control is specified in **3313** and **6812**.

### *3441. A Sextant Fix*

The sequence of events that take place, and the orders and oral reports which are given may perhaps be better understood by the following consecutive relation. The relation is only continued through all of the events in connection with *one* three-point fix, but from this an understanding of the continuous operations which occur can be had. The time of the position is 10:00:00 and all of the data obtained are recorded in the Sounding Record as of this time; other times given below are merely to illustrate the approximate timing of the various activities in connection with obtaining that fix and sounding. It is assumed that a launch party is surveying with handlead and using three-point fix control. The officer-in-charge observes the left angle and there is a right angleman in addition to the recorder.

It must be understood that, in this case, all of the personnel are comparatively close to one another and that all orders, directions, and reports are made orally and can be heard by all concerned. The recorder, leadsman, and coxswain repeat all orders and the recorder repeats all data as he records them. In some cases signal bells may

be substituted, as for instance the recorder may use a bell, or a sounding clock with a bell, to indicate to the leadsman when to sound.

9:59:45 RECORDER to *anglemen:* "Stand by!" (*The anglemen pick up their sextants, find the respective objects in their sextants, and keep their angles approximately on.*)

9:59:50 RECORDER to *leadsman:* "Sound!" (*This order may also be given by whistle, bell, or other signal. The recorder issues this order an appropriate number of seconds before the end of the time interval, depending on the depth, speed of the boat, and skill of the leadsman, so that the leadline will be vertical at the desired time. The leadsman swings the lead and heaves it out ahead of the boat. The lead sinks. The launch approaches the lead. The leadsman hauls in the slack leadline. The anglemen prepare to mark the angles.*)

10:00:00 RECORDER to *anglemen:* "Mark!" (*The leadline is vertical. The anglemen mark the angles. The leadsman reads the depth and . . . . . .*)

10:00:02 LEADSMAN to *recorder:* "Nine—eight." (*The recorder repeats and records 9.8 (fathoms). The leadsman's assistant starts hauling in the leadline, and the leadsman coils it preparatory for the next sounding. The anglemen read their angles, and . . . . . .*)

10:00:04 LEFT ANGLEMAN to *recorder:* "Sixty-seven fifteen." (*The recorder repeats and records 67° 15′. The officer-in-charge sets the left angle on the protractor.*)

10:00:08 RIGHT ANGLEMAN to *recorder:* "Forty-one oh-eight." (*The recorder repeats and records the right angle 41° 08′. The officer-in-charge sets the right angle on the protractor and plots the position. As he plots he announces the names of the stations used in the three-point fix.*)

10:00:20 OFFICER-IN-CHARGE to *recorder:* "The fix is BAT-FIG-OLD." (*The recorder repeats and records the names of the stations. After the position has been plotted the position number is frequently verified. A change in course is ordered if necessary.*)

10:00:40 OFFICER-IN-CHARGE to *coxswain:* "Right two degrees."

COXSWAIN (*repeating*): "Right two degrees. The course is now three twenty-seven." (*The coxswain is now steering a course 2° to the right of the previous course. The recorder repeats and records the new course 327°. For a considerable change in course he also records the effective time.*)

### *3442. An R.A.R. Fix*

Hydrography is most complicated when the soundings are obtained by the echo method and the control is by R.A.R. The sequence of events that precede and follow one R.A.R. position and the approximate times at which these events occur on the average are given in the following relation. It is to be understood that the clock times preceding and following 10:00:00 are varied depending on the efficiency of the personnel, the distance from the R.A.R. stations, and the amount of difficulty experienced in interpreting and plotting the results. The time of the position is 10:00:00 and all of the data obtained are recorded in the Records as of this time; other times given below are merely to illustrate the approximate timing of the various activities in connection with obtaining the fix and sounding at 10:00:00.

The various operations in connection with obtaining an R.A.R. fix take place in different parts of the vessel; the bomber is located at a station on the quarter-deck; the radio technician and the chronograph attendant are stationed in the radio room or in adjacent rooms where they can communicate orally with one another; the other personnel are usually stationed on the bridge or in the chartroom adjacent thereto. The personnel at each of these stations can communicate with the other stations only by signal or by telephone, voice tube, or loudspeaker communication system.

As in **3441** the sequence of events is only carried through one complete position, and it is to be understood that continuous soundings are obtained at regular intervals and the sequence of events described herein is repeated at each successive R.A.R. position during hydrography.

For a more detailed description of the duties of each of the various personnel, reference should be made to **671**.

9:59:00 CHRONOGRAPH ATTENDANT (*or sometimes the bridge*) (*signals the bomber and notifies him the size of bomb to use*).

9:59:02 BOMBER (*signals the chronograph attendant and the bridge simultaneously, acknowledging the signal and notifying them to expect an R.A.R. position on the next even time interval. The bomber prepares the bomb. The radio technician checks the tuning of the radio receiver*).

9:59:45 CHRONOGRAPH ATTENDANT (*or sometimes the bridge*) (*signals the bomber to light the bomb. The bomber ignites the bomb, throws it overboard, and as it strikes the water . . . . . .*).

10:00:00 BOMBER (*signals the bridge and the chronograph station simultaneously that the lighted bomb has been thrown overboard. This is the time of the fixed position. The fathometer attendant reads the depth and silences the oscillator, if sonic. The recorder notes the time and records it in the Sounding Record. The log is read and the log reading recorded in the Sounding Record. The chronograph attendant notes the time and records it in the Bomb Record. The chronograph attendant switches the hydrophone into the chronograph circuit and starts the chronograph*).

10:00:02 FATHOMETER ATTENDANT to *recorder* (*announcing the depth on position*): "Thirty-six point five." (*The recorder repeats and records this depth 36.5* (*fathoms*). *Soundings are continued at regular intervals throughout subsequent events.*)

10:00:10 The bomb explodes. The explosion records automatically on the chronograph tape. (*The chronograph attendant marks the tape to identify this registration of the bomb explosion. He has noted the time interval in seconds between the "bomb over" signal and the explosion and records this in the Bomb Record. The chronograph attendant switches the radio receiver into the chronograph circuit. The chronograph continues in operation and . . . . . .*)

10:00:19 The first radio signal is received from an R.A.R. station and records automatically on the chronograph tape. (*This signal is followed by radio returns from the other R.A.R. stations which are within receptive distance. The chronograph attendant marks the tape to identify each radio return. After the last return has been received the chronograph is stopped, and the chronograph attendant takes the times of the returns from the tape and derives the time intervals, recording all data in the Bomb Record, and . . . . . .*)

10:03:30 CHRONOGRAPH ATTENDANT (*signals the bridge and reports*) *to the officer-in-charge:* "Bomb at ten o'clock flat."

OFFICER-IN-CHARGE replies: "Position twenty-three at ten o'clock flat." (*Chronograph attendant records the number of the position in the Bomb Record.*)

CHRONOGRAPH ATTENDANT to the *officer-in-charge:* "Position twenty-three: ESAU eight fifty-six; DAGO nineteen thirty-five; and GOBY twenty-seven ninety-seven." (*The officer-in-charge records the time intervals in the R.A.R. abstract and repeats them back to the chronograph attendant for verification. The officer-in-charge plots the position on the boat sheet by means of the R.A.R. distances, and orders a change in course if necessary.*)

10:05:00 OFFICER-IN-CHARGE to *helmsman:* "Right two degrees."

HELMSMAN (*repeating*): "Right two degrees. The course is now three twenty-seven." (*The recorder repeats and records in the Sounding Record the new course 327° and the time it was effective. The officer-in-charge issues any other pertinent orders.*)

## 345. MISCELLANEOUS OPERATIONS

There are various operations which occur at irregular intervals in running a sounding line that are discussed under the various subheadings.

### *3451. Beginning of Sounding Line*

To start a sounding line the survey vessel is navigated by the most direct navigable route to the beginning of the proposed line, trial positions being taken as this point is approached and the vessel being turned to head approximately on the course of the proposed line at or astern of the desired starting point. The helmsman is told what course to steer, the recorder is told when to take the first position and sounding, and

if three-point fix control is used, the three objects to be observed are selected and agreed upon.

Where the beginning of the proposed line is so close inshore that, for purposes of safety, it is necessary to start it from a standstill, that fact must be entered in the Sounding Record. A complete time record of the changing speed of the vessel must be kept, and another position fixed as soon as the vessel is traveling through the water at a standard and uniform speed.

### *3452. Trial Positions*

A trial position is a position taken to determine the progress or course of the vessel, or its position relative to the proposed sounding line, but which is not recorded as a part of the official record. Such positions are, of course, frequently necessary before starting a line and often between lines. Their use should be unnecessary while running a sounding line. The purpose of taking positions is to enable the profile being sounded over to be plotted accurately. If the regular interval between positions is so long that the position of the vessel is so uncertain as to require a trial position, the regular interval should be reduced. If an intermediate or additional position is believed advisable to verify the vessel's course or speed, it should be taken and recorded as a part of the official record.

### *3453. Ranges and Distance Angles*

In surveying with the handlead, and at other times when an exceedingly slow speed is required, ranges will be found very useful, especially when there is a cross wind or current. Two shore objects separated by some distance should be selected for use as range marks to assist in running the proposed lines (if practicable, without unduly delaying the work). When a range is desired the correct point on the shoreline may be determined from the offshore end of the sounding line by measuring with the protractor on the boat sheet the angle between some control station and the azimuth of the line being run. This angle is set on a sextant, and with the signal to which the angle was measured in view, a search may be made for a suitable object along the shore which may serve as a front range mark, the corresponding rear range mark being farther inland.

Starting at the inshore end of a line the selection of a front object is easy but it is only after the vessel has advanced some distance offshore that a rear object can be selected to give the correct range.

Distance angles may be used for the same purpose as ranges except that the resulting lines will be flat curves instead of straight lines. Ranges used for systems of radiating lines are described in **3142** and the use of distance angles is discussed in **3143**.

### *3454. Turns at Ends of Lines*

At the end of a sounding line, which is one of a system of parallel lines, the survey vessel turns and runs to the next proposed line. Most systems of sounding lines should be planned so that soundings are not required while the vessel is turning between adjacent lines. The exact positions of such soundings are usually in doubt and there is less confusion if they are omitted. When soundings around turns are not recorded or are not intended to be used on the smooth sheet, a note should be entered in the "Remarks" column of the Sounding Record opposite the last position of a line that the "Line ends," and opposite the first position of the next line a note should be entered that the "Line begins." The expression "Line turns right" or "Line turns left" should be entered

in the "Remarks" column only when a turn is made in a line of continuous soundings or when soundings are taken around the turn and recorded and their use on the smooth sheet is considered necessary by the officer-in-charge. (See also **3463**.) Standard abbreviations for these expressions are given in **8111**.

As a sounding vessel approaches the shore, or other shoal water, a lookout must be kept ahead for rocks and other dangers, the helmsman and engineer must be ready to carry out orders promptly, and the anglemen must be standing by to take a fix before the vessel is stopped or turned. The course must not be maintained in order to obtain a position on the regular interval, if there is any chance of endangering the vessel.

Where the space between adjacent lines is less than is needed to turn the vessel 180°, alternate lines should be run. The omitted lines can then be run by splitting each pair of alternate lines run originally. If this is not practicable, closely spaced lines can be run consecutively by making the turns in the following manner, if there is sufficient sea room. When the end of the line is reached, the vessel is first turned momentarily away from the direction of the desired turn and then the helm is put hard over for the desired turn. The amount to turn in the opposite direction will naturally vary with the spacing of the lines and the turning radius of the vessel. The same result can be attained by turning in the following manner. For a left turn, turn 90° left and run almost to the next line, then turn full right and come around 270°, easing the rudder enough in the middle of the turn so the vessel will be on the desired sounding line when the turn is completed.

### 346. Handling the Survey Vessel While Sounding

The methods and precautions of handling survey vessels of various sizes from the largest ship to the smallest skiff are essentially the same, if allowance is made for the momentum which is proportional to size. In sounding, the first and most important consideration is always the safety of the vessel, and under no circumstances should a large vessel be utilized to survey in dangerous waters which can be more safely navigated by a smaller one. Where there is danger of grounding in examining shoal areas or surveying in areas where dangerous shoals are to be expected, a slow speed should be used and such work should always be performed on a rising tide, preferably just after low water, in order that the vessel, if it grounds accidentally, may be more easily floated. (See also **1581** and **361**.)

In handlead and wire sounding the vessel must always be maneuvered so as to avoid the risk of getting the leadline or wire in the propeller (see **3421**). Using echo sounding the handling of the vessel becomes principally a matter of navigation and seamanship. Further information on handling a vessel when it is necessary to stop to obtain wire soundings is given in **3422**.

#### *3461. Sounding Speed*

For handlead sounding from either a ship or a launch, the maximum speed practicable is approximately 5 knots. When sounding in moderate depths of water from a launch the average practicable speed is about 3½ knots. The correct speed under any conditions may be readily determined and is limited by the following two factors: First, the speed must be slow enough so that all handlead soundings are vertical; and second, it must be slow enough so that the spacing between adjacent soundings is adequate for defining the profile along that sounding line. When sounding with the handlead, the speed must be decreased when running with a fair current in order to avoid excessively large sounding intervals and overrunning the leadline.

Most modern survey launches are capable of operating steadily at speeds sufficiently slow for handlead sounding. When the slowest speed at which a launch will operate satisfactorily is still too fast for handlead sounding, funnel-shaped canvas drags will be found an efficient means of slowing the launch to the desired speed. They may be towed astern by a simple arrangement of lines to adjust the amount of effective drag or to spill them when desired to make them noneffective. They may also be used to obtain a shorter turning radius than is normal for the launch and to assist in stopping for wire soundings in order to reduce wear on the clutch. For temporary use, if canvas drags are not available, one or two buckets can be substituted to obtain the same results.

Echo soundings may be taken at any practical rate of speed. A vessel using echo sounding should be operated at a standard speed which is efficient as to accomplishments and is economic as to fuel consumption. The standard speed must be reduced in areas where dangers are suspected or where there is danger of grounding. When the interval between fixed positions cannot be shortened, the speed must be reduced so that the proposed sounding lines can be followed reasonably well and there will be no uncertainty in the positions of the intermediate soundings.

When soundings are obtained between fixed positions a uniform speed of the sounding vessel must be maintained between consecutive positions so that the intermediate soundings may be spaced with reasonable accuracy. Changes in speed should be made only at the times of fixed positions, and an additional position should be taken for this purpose, if necessary, as when approaching the shore or when a dangerous shoal area is encountered unexpectedly. In such cases the launch may have to be turned, stopped, or backed instantly and a fix should be obtained at the time this occurs. If it cannot be obtained, the time must be noted.

The time and amount of any change in speed must be entered in the Sounding Record whether or not a position is obtained, the amount being noted in the "Remarks" column.

The construction and use of graphic speed scales in hydrography are described in **4826**.

### *3462. Following Proposed Lines*

In hydrography, an effort should always be made to follow the proposed lines as indicated on the boat sheet (see **3241**).

The greatest care should be taken to make the actual sounding line coincide with the proposed line when the lines are parallel to the coast and, when a position plots off such a line, to return to it as soon as practicable. For other lines coincidence is not as essential as is uniformity in spacing over the entire area. In many cases, if a position plots some little distance off the proposed line, it may be desirable to change course only enough to parallel the latter and then to shift the entire system of future lines to agree with those actually run. (See also **3141**.)

Where the use of ranges or distance angles is impracticable, the sounding vessel is kept on, or as near as practicable to, the proposed line by small changes in course made after each fixed position has been plotted and the relation of the vessel's position to the proposed sounding line has been determined. It is only after considerable experience has been gained that this can be done quickly and by the correct amount. By the time the data are available on which to base the amount of the change, the vessel has moved beyond the plotted position and this fact must be taken into consideration in judging the amount of change necessary to bring the sounding vessel back on the line. When the positions are fixed by strong three-point fixes, the plotting of which con-

sumes only a small part of the total time interval between positions, the problem is comparatively easy. As the three-point fixes become weaker and there is less reliability in the plotted positions, and as their plotting requires a larger proportion of the total time interval, it is increasingly difficult to judge whether to make a change in course and, if so, how much.

In R.A.R. the problem is more complex. The position data are usually not available until 4 or 5 minutes after each position and, if the position plots off the line, by the time this is known, the vessel may be much farther off the line if on an erroneous course. Added to this is the fact that the R.A.R. method of control is often not sufficiently precise for the relation between two consecutive positions to be used with assurance for this purpose. The hydrographer must be an expert judge of dead reckoning to decide whether or not to trust the R.A.R. data for this purpose. (See **6824**.)

### *3463. Changes in Course and Turns*

If practicable, a fixed position should be obtained at each change in course greater than 10°, and the effective time of all turns must be entered in the Sounding Record.

For most survey scales a turn of 90° or less by a small launch may be assumed to occur instantaneously and need not be plotted as a curve. For a ship, a change in course greater than 10° should be plotted as a curve to represent as nearly as practicable the actual track followed, taking into account the turning radius of the vessel and the time spent in the turn. In such cases the times of starting and completing the turn must be entered in the Sounding Record.

A large vessel has considerable momentum and does not start to turn until some time after the rudder has been moved. This tendency of a large vessel to maintain its original course must be taken into account in plotting the vessel's track around turns. When the turning radius of the vessel is known, the curved track around a turn should be plotted backwards from the fix, or position of the vessel, after the completion of the turn. There will then be a gap between the beginning of the turn and the position before the turn which should be connected by a straight line. The momentum of the vessel makes the component of distance traveled in the direction of the original course roughly twice as great as that traveled in the direction of the new course. (See also **7682**.)

The turning radius of each survey vessel at sounding speed should be determined and the amount should be noted in the Descriptive Report of each survey sheet (see **842*C***). The turning radius may be determined by plotting at a large scale successive strong three-point fixes observed as rapidly as practicable, the various movements of the steering wheel being correlated therewith.

For dead-reckoning or R.A.R. controlled hydrography on large scales the following method may be used to determine the relative position of the ship before and after a turn: A large paper carton or wooden box, or similar object, is thrown overboard at the beginning of the turn and the time noted. It is kept in view until the ship has completed the turn and steadied on the new course when the time is again recorded and the bearing of the carton is observed by pelorus and its distance is determined by a depression angle.

### *3464. Sounding in Currents*

It has been definitely established that neither handlead nor wire soundings can be accurately obtained or located when the sounding lines are run across or against strong currents. The measured depths will be invariably greater than the true depths, the error being in direct proportion to the strength of the current and increasing greatly

with the depth. It is assumed that a bight is formed in the leadline by the current acting on the submerged portion of the line and the lead, so that when the line apparently leads vertically down from the leadsman's hand the lead is actually slightly downstream and the bight of the submerged portion of the line is still farther downstream. The force of the current puts a strain on the bight so that the leadsman is deceived into believing he is getting a vertical cast.

To eliminate such discrepancies, therefore, handlead sounding should be done only at slack water or from a boat drifting or running slowly with the current. Crosslines or lines nearly normal to the channel should be run only at slack water and lines in the direction of the current always run with it.

A similar type of error can be introduced in handlead sounding in strong currents by the leadsman permitting the lead to remain on the bottom for a short interval before reading the depth. In such cases the leadsman should be instructed to read the depth the instant the lead touches bottom. When searching for least depths in an area where current prevails, the lead must be rapidly lifted off the bottom and dropped until the least depth has been found. The lead must not be allowed to remain on the bottom appreciably because the current will form a bight in the leadline to indicate a depth greater than the actual depth.

Echo soundings are not affected in the above manner; and, when practicable, this method of sounding should be used in areas where strong currents prevail, both because errors in verticality are eliminated and a faster speed and better control of the survey vessel may be maintained.

Another error may be introduced when sounding in strong currents that affects the spacing of soundings between positions and thus is applicable whether the soundings are handlead, wire, or echo. If a launch used in running sounding lines across a channel where there is a strong current is kept on line by the use of ranges, progress along the line will not be at a uniform rate of speed due to the varying strength of the current at various places in the river or channel. In the strongest current the progress across the current is slowed because the vessel must be headed into it more to counteract its effect. On the contrary, this force will diminish near the edges of the channel and there will be some places where there is no current at all. Insofar as practicable, fixes should be taken at short enough intervals and at places where the strength of the current changes so that the correct spacing of the intermediate soundings will seldom be in doubt. If this is impracticable, such crosslines should be run at slack water.

Varying currents are found in the vicinity of shoals and rapidly changing depths. Even far offshore these erratic currents make the running of the proposed lines difficult. This is especially true where a sounding line crosses the edge of a shoal area where currents of different velocities or directions are found. Sometimes there is visual evidence of such a change in the current, but frequently the evidence is not pronounced or sufficiently noticeable to give warning of its presence. An experienced hydrographer will suspect the presence of such currents from the submarine relief, and an attempt should be made to anticipate their effect on the track of the vessel. It is often practicable to make a change in course which will at least partly counteract the effect of the current before evidence of its effect has been given by the consecutive plotted positions. In localities where strong currents of this nature are apt to be encountered, especially if the spacing of the lines is comparatively close, the greatest difficulty is experienced in running the proposed lines accurately enough to avoid the necessity for splits.

When the effect of such a current has not been foreseen in time and the plotted position of the vessel is found to be considerably off line, with a trend which will take it farther yet from the line, it is sometimes advisable to make an S-shaped change in course to put the survey vessel back on the proposed sounding line. This maneuver is the same for a large survey ship as for a launch, except that it can be more quickly effected in the case of a launch. Assuming that the position of the vessel has plotted considerably to the left of the proposed line, as soon as this fact is known, the rudder is put full right to make a change in course not exceeding 90° for the estimated time necessary to maneuver back nearly to the line, when the rudder is put full left to resume the original course, or rather a new course a few degrees to the right of the original one.

The length of time to run on the turn can be determined only by experience. In a launch which turns quickly a run actually normal to the proposed line may be made. In the case of a large survey ship the momentum of the ship prevents such a quick turn and during the entire maneuver the ship is usually turning first to the right and then to the left without having been steadied on any intermediate course. The times of the various parts of the maneuver must be recorded accurately so that the actual track of the vessel may be plotted on the smooth sheet. When three-point sextant fixes are being used, a fix should be obtained just before the maneuver is begun and just after the vessel is steadied on the new course, if practicable.

#### *3465. Keeping a Lookout*

When surveying in areas where dangers to the survey vessel may be encountered, a sharp lookout must be kept at all times. In handlead sounding from a launch an adequate lookout can be kept by the leadsman, the coxswain, and the junior officer when the last is not otherwise engaged. On a survey ship and a launch taking echo soundings, a man whose sole duty it is to keep a lookout shall be stationed in the most strategic position whenever the vessel is surveying in an area where unexpected shoals or dangers may be encountered. In some regions, especially where the bottom is coral, a lookout stationed aloft on a survey ship or at the greatest practicable elevation on a launch will be able to detect shoaling by the appearance of the water and, in addition to warning the officer-in-charge of possible danger, will often sight shoals abeam which would otherwise be missed on the regular system of lines. (See also **361** and **3623**.)

## 35. ADEQUACY OF HYDROGRAPHIC SURVEY

In general, to be adequate the survey of any region should be sufficiently intense and complete to determine the depths and the character of the bottom and to locate all dangers and other features that should be charted for the guidance of the mariner. The adequacy of a survey has a direct relation to the scale of the sheet on which it is plotted—it is obvious that a completely adequate survey cannot be made on a scale too small to plot the lines and soundings at the spacing required for a thorough development of the area. In certain circumstances the Chief of Party has the authority to increase the scale of a survey on his own initiative, and where he does not have this authority he should not hesitate to recommend for the approval of the Washington Office a larger scale of any area, when considered desirable (see **1214** and **123**).

### 351. A Basic Survey

Hydrographic surveys may be classified as basic, revision, special, and reconnaissance. The project instructions will specify which is required.

A *basic* survey is fundamental; it must be so complete and thorough that it does not need to be supplemented by other surveys, and it must be adequate to supersede, for charting purposes, all prior hydrographic surveys of the area, except for some few features which may be retained from the old survey (see **9343** and **9344**). It must be adequately controlled by the best practicable means in current use; it must be sufficiently intense to discover and determine the least depths on all dangers to navigation; it must verify or disprove beyond question all dangers, critical depths, and other features important to navigation appearing on the charts or prior surveys; it must develop submarine features of importance in navigation; and it must provide sufficient permanent control so that future revision surveys will require the establishment of a minimum of additional control.

It need not cover channels and other inshore areas, recently surveyed adequately on as large or a larger scale by a surveying organization such as the United States Corps of Engineers, provided that survey is adequately controlled and can be correlated with the basic survey and a satisfactory agreement of depths is obtained at the junction of the surveys.

The project instructions will specify any features of prior surveys that need not be verified or disproved, or superseded, as for example, bottom characteristics (**3842**), least depths found by prior wire-drag surveys (**3523**), etc.

## 352. Previously Known Dangers and Shoal Soundings

All previously known or reported dangers and shoal soundings must be proved or disproved by the hydrographic survey unless the project instructions specify otherwise. The prior surveys and the published charts covering the project area shall be scrutinized for such features. The Descriptive Report shall contain a statement that a thorough comparison has been made and that the new survey is adequate to supersede completely the old data if such is the case (see **842***L*). When a danger or shoal indication shown on a chart, survey sheet, or publication is not found during the current survey, the examination must be thorough enough to disprove positively its existence, and the records must show the kind of an examination made and its duration, and the Descriptive Report must state why the danger is believed to be disproved; otherwise no previously reported danger can be removed from any publication. (See **842***N*.)

Where a shoal is discovered during the new survey close to a previously known one, sufficient examination must be made to determine definitely whether the new feature is a separate shoal, an extension of the original one, or a more accurate location of the original one.

### *3521. Verification of Prior Hydrographic Surveys*

A sufficient examination must be made to prove or disprove the existence of every danger, shoal sounding, shoal indication, bare rock, and wreck on prior surveys within the project area. It is not sufficient merely to verify their existence; their positions, the least depths on the submerged features, and the elevations of the exposed ones must be determined. It should be borne in mind that many prior surveys were made during a period of evolution of both field and office practices. Field methods were frequently below present standards and control was sometimes insufficient, making coordination with new well-controlled surveys difficult.

Where the existence of a feature is disproved, or where the examination is not considered adequate to disprove its existence, the Descriptive Report must contain a full explanation and a recommendation for disposition of the previous data. If the

new survey finds a minimum depth on a submerged feature which is greater than that shown on the prior survey, the Descriptive Report must explain the discrepancy and contain a positive recommendation by the hydrographer as to which depth should be used for charting and why (see **842***N*).

The depth curves and all critical soundings should be transferred in red to the boat sheet from copies of the prior surveys (see **3234**). This will afford a comparison with the prior surveys as the new survey progresses, and will also avoid the possibility of overlooking soundings which should be investigated. The curves are helpful as a warning of the general depths to be expected and, if sounding is by handlead, the leadsman can be warned when to expect deeper or shoaler depths so that he will not *miss* soundings that would have to be supplied later.

Where the general depths on a new survey differ consistently from those on prior surveys, or the least depths on shoals disagree similarly, a report should be made to the Washington Office and instructions should be requested before extensive field examinations are made to determine the reason. When such a discrepancy is known, an examination of the records in the Office may disclose a reason for it which will preclude the necessity for further extensive examination.

### *3522. Verification of Charted Features*

The published charts are based on the surveys of this Bureau but in addition they incorporate information from a variety of sources, such as surveys of other organizations, reports of vessels grounding, reports of shoal soundings taken by vessels in transit, and reports of breakers. Many of these may be of doubtful accuracy and reliability, but as a matter of safe policy they must be added to the charts.

After all data which need verification have been transferred from the prior surveys to the boat sheet, the latter must be compared with the largest-scale charts of the latest date of the area, and any additional similar data must be transferred to it from the charts (see **3235**). These data require the same examinations and reports as are required for features originating with prior surveys (see **3521**). Unless charted data from sources other than the prior surveys are quickly verified, the Washington Office should be consulted regarding the facts of their origin. The records will often disclose the reliability of the charted data; and if unreliable, whether the depth or the position is most likely to be in doubt and if the latter, how much.

The old surveys did not receive the close examination and review in the Washington Office that surveys of today receive, and it will be found occasionally that erroneous interpretation or application of the original data was made when they were applied to the charts.

### *3523. Prior Wire-Drag Surveys*

Where an adequate wire-drag survey has been made in a nonchangeable area, the dangers, shoals, and the least depths originating with the wire-drag survey need not be verified unless this is specifically called for in the project instructions. Ordinarily, the dangers and shoals originating with an adequate wire-drag survey may be considered final and adequate for charting without further investigation, except in a changeable area. Obstructions and dangers to navigation, however, may have been removed.

If the wire-drag survey is in an area of considerable importance to navigation the hydrographer must consult with the United States Corps of Engineers to learn whether any of the dangers and obstructions have been removed by blasting or dredging. If

so, a new least depth on each of those so affected must be obtained from that agency or a hydrographic examination made to determine it. Rocks and obstructions supposed to have been removed by blasting should be wire-dragged, if possible, to ensure that they have been removed in their entirety, unless they have been properly dragged after removal by the agency responsible for the removal.

### 353. Depth Curves

Depth curves are indispensable for interpreting and examining a hydrographic survey. There is no better gage of its completeness, adequacy, and accuracy than the ability to draw closely spaced depth curves with an assurance that the submarine relief is accurately depicted. The depth curves should be drawn on the boat sheet by the hydrographer as the work progresses, and a careful interpretation of the data will disclose where the lines have not been spaced closely enough, where additional development is required, and where errors have been made which require investigation.

An adequate representation of the submarine relief by depth curves is a problem similar to the representation of land topography by contours, except that the topographer has the opportunity to examine visually the topography of the area whereas the hydrographer has only the measured depths as his guide. The hydrographer should make a study of the characteristic bottom forms, as such forms usually repeat themselves in the same region and in similar regions.

Abnormal or improbable depth curves are strong evidence of inaccuracies, inadequacies, or possible errors in the hydrographic survey or the inking of the soundings, and where they result from the data, the soundings and positions should be carefully scrutinized. On extensive coastal shelves, such as exist on the Atlantic and Gulf Coasts of the United States, the depth curves are generally smooth and regular because the bottom forms are the results of wave or tidal current action on the loose materials generally found on the bottom. On the continental slopes, however, in depths greater than about 100 fathoms, the bottom forms are generally similar to those found on land. In general, an interval of 25 fathoms between depth curves is adequate for the continental slopes and the deeper waters off the Pacific and Alaska Coasts. (See **3533**.)

To draw closely spaced depth curves carefully and accurately requires the inspection and consideration of each sounding not only once but often several times, whereas in sketching widely spaced depth curves many of the intermediate soundings may not be considered at all and important indications may be overlooked.

In this respect some topographic experience is a great asset as is also the ability to recognize predominating physiographic shapes from preliminary sketched depth curves. The ability to represent submarine relief by means of depth curves is acquired only by intensive training and practice and by study of similar work which has been done by an experienced hydrographer.

Depth curves ordinarily cannot cross or run abruptly into each other. On approaching one another they tend toward parallelism. In general, the information from sounding lines should be sufficient to permit the delineation of continuous curves. Special care must be exercised to avoid excessive spacing of the sounding lines where their direction is parallel to the depth curves.

#### *3531. Similarity of Submarine Relief to Adjacent Land*

A study of the nature of the land adjacent to the project area is often helpful in developing the depth curves. The submarine relief is likely to be similar to the adjacent

land topography, and reference should be made to any well-contoured topographic sheets of the area. (See also **355**.)

### *3532. The Low-Water Line*

The low-water line is the depth curve of zero depth. Its position is best determined by the hydrographic survey. In areas where it is practicable and can be done without endangering the personnel or the equipment, the low-water line and the adjacent offshore depth curves shall be completely and adequately defined by lines of hydrography run over the area at high tide which, when reduced to the sounding datum, will define the low-water line. The survey shall be planned so that the sounding lines closest inshore may be run at or near high tide and when the sea is calm. (See **3121** and **3122**.)

Where for any reason, it is impracticable to define the low-water line by soundings, it should be delineated from the topographic survey (see **754**).

### *3533. Depth-Curve Interval*

No single requirement for the spacing of depth curves can be prescribed to apply to all regions. In an area of steep slopes and irregular submarine relief it is considered sound practice to draw all the curves that the scale of the boat sheet will permit. Such a close spacing of the depth curves is obviously not required in areas of gently sloping bottom with practically no irregularities, such as exist off the Gulf Coast. A good general rule is that the depth curves should be drawn so far as practicable according to the following intervals:

At 1-fathom intervals to 10 fathoms.
At 5-fathom intervals in depths between 10 and 50 fathoms.
At 10-fathom intervals in depths between 50 and 100 fathoms.
At 25-fathom intervals in depths greater than 100 fathoms.

On steep slopes it will frequently be impracticable to draw the depth curves at these intervals and a larger interval may be selected. (See also **7761**.)

## 354. ADEQUACY OF THE GENERAL SYSTEM OF LINES

The spacing of the systematic sounding lines of the survey is not intended to be close enough to pass directly over the shoalest part of any danger, but it is expected that the spacing will be close enough to give at least an indication of every danger and permit the accurate delineation of the depth curves, except for unexpected irregularities of the bottom.

The Chief of Party should not hesitate to decrease the sounding-line spacing prescribed in the project instructions, if this appears desirable, in portions of the general area, in areas where the nature of the adjacent topography indicates the possibility of hidden dangers, where ships are likely to approach the land as in anchorages, and off projecting points and promontories. It is especially important to do this in previously unsurveyed regions where sufficient data may not have been available as a basis for the spacing specified in the project instructions.

Where the spacing is generally adequate, it should be split in areas of unusual bottom irregularity, over extensive shoal areas, and where the sounding lines run have diverged so far from the proposed ones as to give a spacing one-third greater than the instructions call for. Splits should also be run where the depth curves parallel the direction of the sounding lines and the spacing is inadequate to fix them accurately in position.

The specified system of sounding lines is based on an expected type of submarine topography and where unexpected irregularities are disclosed the spacing must be reduced in these areas.

Harbors and anchorages are ordinarily surveyed at larger scales and with a closer spacing of sounding lines than is specified for the general area. Additional sounding lines shall be run in any bight or indentation in the coast in which a vessel might anchor, even though a larger scale is not specified nor is deemed necessary by the Chief of Party.

### *3541. Holidays*

No *holidays* should be left in the hydrographic survey. A holiday is not likely to occur within the area of systematic sounding lines on one survey sheet but it may occur at junctions with prior surveys, at junctions between surveys on different scales or by different sounding units, and sometimes where a change is made in the spacing of the lines. Before leaving the working ground, and in the case of buoys before removing them from their positions, the Chief of Party must assure himself that no holidays have been left in the project area which might necessitate a return to the area or the reestablishment of expensive control.

### *3542. Missed Soundings*

*No bottom* leadline soundings are not satisfactory and if they cannot be avoided in important areas, definite measured depths must be obtained later. Where such soundings occur near the outer limits of an area due to the general depths being too great for the method of measurement, the area surveyed on the adjacent sheet by other methods must overlap to a junction with definite soundings.

Echo soundings are sometimes missed because the apparatus is not functioning properly or because the conditions prevent the echo from being received. In important areas where soundings are missed because of improper functioning of the apparatus, the line should be repeated at a later time and additional soundings taken. In other cases they need not be repeated except where consecutive misses along a sounding line create a gap longer than the space between adjacent lines.

In deep water, when the apparatus is functioning properly and no echo can be heard, one additional attempt shall be made to obtain the soundings at a later date, and if this is not successful, the area may be omitted if of not too great an extent. If of large extent, wire soundings should be taken.

Each time that echo soundings are missed the reason therefor shall be stated in the "Remarks" column of the Sounding Record.

When the echo-sounding apparatus intended for use in deep water repeatedly fails in such depths the Washington Office shall be notified in a report containing all the facts and the supposed reasons therefor.

## 355. DEVELOPMENT

A great responsibility rests on the modern hydrographer. Vessels of great size and value navigate areas with a minimum depth of water under their keels, trusting implicitly in the charts to avoid dangers. The possibility of the loss of or damage to a vessel by striking some uncharted danger must always be borne in mind by the hydrographer. It is only by a close spacing of soundings and sounding lines and a thorough examination of all irregularities of the bottom that there can be any reasonable assurance of the completeness of a survey.

The general system of sounding lines is intended to cover the area systematically and determine the general depths. The spacing of the lines and soundings should be close enough so that at least an indication of every shoal or danger is given. Extensive experience is not required in the mechanical operation of running systematic sounding lines, but it must not be assumed that the general system of lines will adequately survey an area. The development of the indications furnished by the general system is always the most important part of the work and frequently the most extensive.

The extent and kind of development needed in a region is often disclosed by a study of the adjacent land forms. For example, in certain water areas along the New England Coast, sunken boulders, corresponding to those that dot the fields along the shore, are found in great numbers, while in southeast Alaska the sharp mountain peaks, that are so noticeable while cruising along the coast, are duplicated under water as submerged pinnacle rocks, often rising from great depths to within a few feet of the surface. On the South Atlantic Coast of the United States the low even sandy coasts give assurance that dangers, such as rocks and reefs, do not exist, but here it will be found that, corresponding to the constant movement of the sand dunes along the shore under the effect of the wind, there are frequent changes in the bottom due to the action of waves and currents.

A mountain range, or ridge, gradually decreasing in elevation to a rocky point at the shore, is likely to be extended into the water in the form of a submarine ridge or a series of shoals. Near the axis of a chain of islands, submerged features of a similar nature are likely to exist.

For the adequate development of these indications and such features as channels, anchorages, and areas inside the 10-fathom curve, modifications of the methods used in the systematic survey are often required to secure a complete and economic development of the features.

Development must be distinguished from examination. Development is to ensure that there are no dangers in the area, to provide for the accurate delineation of the depth curves, and to locate the positions of existing dangers. Development is not expected to furnish the least depths on dangers and shoals; these are obtained by examination (see **366**).

The extent of the development will vary from a maximum on shoal areas in important locations and in channels and anchorages having depths near the draft of vessels to be accommodated, to a minimum on extensive shoal flats, over which navigation is not expected, and in clear areas of much greater depth than required for navigation. (See also **367** and **368**.)

Shallow channels and navigable waters that are likely to be used by shallow-draft vessels or motorboats must likewise be developed.

In regions where changes are continually taking place, development ordinarily need not be so detailed as in regions of little change.

The development of all shoal indications is one of the most essential details of hydrographic surveying. In order that all soundings indicative of possible shoals may be noted, close cooperation between the hydrographer, the recorder, and the leadsman or fathometer attendant is essential. Shoals should be developed by a closely spaced system of crosslines to determine the positions of the least depths at which a marker buoy may often be anchored as a guide in the subsequent examination (see **3665**).

Where irregularity in depth is disclosed during the survey or where it may be expected from the rocky nature or formation of the coast, the slightest indication of a danger or shoal must be thoroughly developed. The narrow tongue of a shoal either

isolated or extending from a reef or point of land may exist between two lines of soundings, even though these are closely spaced. A few crosslines in such places will considerably diminish the chance of missing such an extension.

Particular attention must be paid to the areas within the 10-fathom curve where the closest development is especially necessary.

Extensive development may often be avoided if an area can be examined with the wire drag (see **3663**).

### 356. Ranges, Bearings, and Sailing Lines

In the project area all useful ranges, bearings, and other marks for clearing dangers or passing close by them shall be noted. Ranges which are established by the United States Coast Guard, and ranges, sailing lines, and courses which are recommended by the hydrographer must be closely sounded over. One line of soundings shall be run along the centerlines of channels and along ranges and recommended courses, and this line shall be paralleled by one or more lines closely adjacent on each side of the centerline. Where bars exist at the entrances to rivers these shall be sounded over thoroughly, and the best course across them determined and sounded over as specified above. (See also **3833**.)

In areas where there is little navigation and consequently few established aids to navigation, leading and clearing lines are especially valuable to the mariner, and the hydrographer should be constantly alert to select and recommend any that may be of value. One of the most essential requirements for such marks is that they should be readily recognized by a stranger from the given description. The two range marks which indicate the leading or clearing line should be a considerable horizontal distance apart so that the range will be quite sensitive, but rear range marks which are high or very distant should be avoided as they may often be obscured in hazy or cloudy weather.

All ranges, bearings, courses, etc., recommended for use by the hydrographer shall be described in the Descriptive Reports and shown on the sheets in accordance with **7845** and **842***O*.

In the project area all prominent natural objects and natural ranges that may be useful in determining deviations of ship magnetic compasses and in verifying gyrocompasses shall be located and the azimuths of the ranges determined.

The Chief of Party shall determine such azimuths from piers and wharves to prominent natural objects, as are desired locally for use in setting gyrocompasses in the true meridian. The Chief of Party shall inquire at each navy yard, naval establishment, and commercial shipyard, and of each compass adjuster operating in the area, if these are desired, and from which places. He shall cooperate by determining these and shall report the results directly to the interested person or establishment. The results need not be sent to the Washington Office, but mention of what was done should be included in the season's report.

### 357. Crosslines

Crosslines are intended to disclose discrepancies resulting from the use of a faulty plane of reference; discrepancies produced by surveying in unusual conditions of wind, sea, and current; a temporary operational fault in the sounding apparatus; inadequacy or weakness in the control; and incorrect reduction of the records. (See **7771**.)

Crosslines shall be run for the purpose of verifying the accuracy of the survey and the control under the following conditions:

(*a*) All launch and small-boat hydrography shall be verified by crosslines to the extent of 8 to 10 percent of the principal system of lines exclusive of development.

(*b*) All ship hydrography in the Gulf of Mexico, on the Atlantic Continental Shelf south of Cape Cod, and in other areas of fairly regular bottom shall be verified by crosslines to the extent of 5 to 6 percent of the principal system of lines exclusive of development.

(*c*) In all areas where the control is so weak as to prevent the drawing of the depth curves with confidence, the principal system of lines shall be supplemented by crosslines to the extent of 8 to 10 percent, to aid in adjusting the principal system of lines.

(*d*) Except as specified in (*c*), crosslines need not be run in areas of ship hydrography in comparatively irregular submarine relief because in such areas they are of very little value for checking purposes.

Crosslines need not be run normal to the principal system of lines. Any angle of crossing of 45° or greater may be considered satisfactory. Crosslines should be planned to obtain a uniform distribution as economically as practicable. When practicable, crosslines should be run under conditions of tide, wind, and weather different from those obtaining when the principal system of lines was run and using different control.

Crosslines should never be run prior to the completion of the main system of sounding lines since the purpose of the crosslines is to check the principal lines.

### *3571. Discrepancies at Crossings*

Discrepancies at crossings may be systematic or accidental. They should be recognized as evidence of some fault in the apparatus, method, or record, requiring a study to discover its source and to indicate the most probable correction—possibly a reexamination in the field. If the study does not result in an actual correction of one of the lines it may plainly show good reason for the rejection of one and consequently warrant the adoption of the other.

The allowable discrepancies in depths in any given area should be based on the amount of horizontal displacement corresponding to the differences in depth, rather than a percentage of the depth. In comparatively even bottom a difference of 2 or 3 feet may be excessive because of the lateral displacement of the depth curve. On the other hand, in areas of more irregular bottom, a difference of several fathoms may be readily allowable since this may not affect the position of the depth curve appreciably. It must be borne in mind that a discrepancy at a crossing may be due to either a difference in soundings or an error in horizontal position. In any study of discrepancies this fact must be taken into consideration. In general, in the lesser depths the differences at crossings should average not more than 5 percent of the depth and in greater depths not more than 2 percent of the depth. When an examination of the data does not disclose a reasonable explanation of differences greater than these nor a method of adjusting them with confidence, the work should be revised in the field. (See also **7771**.)

## 36. DANGERS AND SHOALS

A hydrographic survey may not be considered complete and adequate until there is reasonable assurance that all dangers to navigation and shoals existing in the area have been found and the least depths on them determined.

## 361. Danger of Surveying Shoals

The survey of dangers and shoals is one of the most important phases of hydrographic surveying, but it is also by far the most dangerous, and where this constitutes a considerable portion of the work the hydrographer must beware of an overconfidence which may lead him to take unnecessary risks with the survey vessel. Whether a search is being made, a least depth being determined, or the existence of a reported shoal being disproved, there is always the danger that the survey vessel may strike or ground and be damaged or sunk with possible loss of life.

In the survey of dangers and shoals, then, the hydrographer must always be alert to the potential danger. Areas where shoals are known or suspected to exist should be surveyed from launches to where a junction can be made safely from the survey ship. The ship should not be endangered just because a launch is not available at the time. Whatever vessel is used to survey in the vicinity of a potential danger, it must be run at a conservative slow speed whenever there is risk of striking bottom or grounding.

Safe passing distances cannot be prescribed for survey ships, or launches, when surveying in the vicinity of a danger, because of the great variety of conditions and circumstances which may arise. Each case must be decided on its own merits by the Commanding Officer, or the hydrographer, who may be expected to have gained sufficient experience to exercise his own judgment. In general, shoals must be surveyed and developed, but property and life should not be unnecessarily risked to do so. No vessel should ever be endangered when the duty can be adequately performed from a smaller one; no potential danger should be approached or surveyed from a ship when a launch can be used; and no launch should be risked when a whaleboat or pulling boat can be used.

When surveying a potentially dangerous area from a launch the same precautions should be taken as when surveying in the vicinity of one from a ship (see **1581**).

When surveying in the vicinity of a known danger or shoal, the hydrographer must beware of overconfidence arising from the fact that he has a position of it plotted on his sheet and that a previous depth was obtained on it. He must not endanger his vessel by surveying too close to a danger, trusting to the fact that the position of the vessel plots at what is apparently a safe distance from it. Any one of a number of factors, or a combination of them, may endanger the survey vessel, although the hydrographer believes he is keeping well clear of the danger.

Before approaching or surveying in the vicinity of a potential danger, the hydrographer should review all the facts and make a careful study of all depth curves and all previous soundings in the vicinity and take into account all possibilities. Some of the factors that may contribute to a vessel being endangered when in the vicinity of a known shoal are the following:

(*a*) Although the danger is visible, other submerged dangers may be in the immediate vicinity.

(*b*) Although a danger has been previously reported as visible, or indicated by breakers, tide rips, or kelp, it may not be visible at the time approached, owing to a difference in tide, current, or sea.

(*c*) There is likely to be less water than the least depth previously reported.

(*d*) Abnormal currents are likely to be found in the vicinity of a shoal, which may set the survey vessel toward the danger between fixed positions.

(*e*) The known position may be in error; the danger may have been charted from a report, from a reconnaissance survey, or from a survey controlled by less accurate methods than are now available.

(*f*) The position may have been transferred wrong, due to an error in plotting, a change in datum, or a misinterpretation of the data.

(*g*) Although the position of the danger is correctly shown on the boat sheet, the positions of the survey vessel may not be relatively correct, due to distortion of the boat sheet, weak control, inaccurately located or plotted control, weak three-point fixes, etc.

(*h*) A different method of control, or plotting, may make relative differences between the plotted positions of the vessel and the position of the shoal; such as R.A.R. versus three-point fix control, buoy control versus control from distant mountain peaks, plotting by *circles* versus three-point fixes.

(*i*) A combination of small errors and inaccuracies may assume a magnitude sufficient to prove serious when surveying in close proximity to a danger—errors such as small errors in sextant angles, small protractor errors, small errors in the plotted control, distortion in the boat sheet, the inherent limitations of a small scale.

## 362. Sources of Evidence

The existence of dangers and shoals is disclosed by four generally different procedures:

(*a*) Through indications obtained during the systematic survey.
(*b*) Through local reports.
(*c*) By the shoal itself, or evidence of it, being seen.
(*d*) By the examination of air photographs.

As such indications are discovered, their probable locations should be noted on the boat sheet for further examination to determine their limits and the least depths over them (see **3242**).

### *3621. Evidence From the Survey*

The spacing of the systematic sounding lines and the intervals between soundings along the line are selected with a view to giving at least an indication of the dangers and shoals within the area. It must not be assumed that the least depth will thus be determined in any case. In fact, it is extremely unlikely that any line of soundings will pass directly over the shallowest part of a shoal so that the least water will be obtained at that time. It is, however, expected that some indication of the existence of a shoal will be shown on the nearest line or lines. Such an indication will occur as a break in the continuity of the slope of the bottom. A more positive evidence of the existence of a shoal is found where two adjacent lines of soundings each contain similar indications. Splits should be run to determine its extent more accurately.

Where a sounding is obtained on one of the regular lines which shows even a slight change from the average depth it should be regarded as a possible indication of a shoal. Where such indications occur a very careful and thorough development of the area shall be made to locate more accurately the probable position of the least depth regardless of any prearranged system of lines. The indications obtained which require further investigation should be marked in red on the boat sheet by the hydrographer or the Chief of Party to indicate whether additional splits only are required or an investigation is necessary. This decision as to the number of split lines or the amount of development or investigation required is a particularly important one requiring extensive experience in hydrography. The Chief of Party is finally responsible for the thoroughness of the survey.

Rocky bottom being felt by the leadsman in an area of predominantly mud or sand bottom is an indication requiring examination.

The hydrographer or the Chief of Party must examine the boat sheet periodically with the utmost care and select the soundings requiring further attention. In many localities it is out of the question to examine every shoal indication, nor is this required. In making the selection the importance of the locality and the types of shoals or dangers to be expected must be considered.

In the selection, hydrographers should be guided by the following considerations:

(*a*) In general depths of 10 fathoms or less in a navigable area, all indications should be examined.

(*b*) All shoal indications rising more than 10 percent from the general depth should be examined.

(*c*) The nature of the bottom should be considered. If it is rocky there is more likelihood of a dangerous shoal and consequently it is more important that all indications be examined. If the bottom is of sand or mud it is probable that the least depth may already have been determined or at any rate there is little likelihood of the existence of an important danger or shoal.

(*d*) The importance of the region from the point of view of navigation should be considered. In a channel, harbor, or area frequently navigated every slightest indication must be examined; whereas in a region little frequented for navigation the number of indications to be examined may be somewhat reduced.

### *3622. Local Reports of Shoals*

In all project areas pilots, fishermen, mariners, yachtsmen, local authorities, and others with local knowledge should be consulted freely for the purpose of collecting hydrographic information, and all reports of rocks, dangers, or shoals must be investigated. In the past the results of such contacts have been very fruitful. Most of the rocks and dangers known to such local authorities are already charted, but frequently the existence of a new rock previously uncharted will be disclosed. Most of the authorities mentioned above, except fishermen, do not know the exact locations of such shoals or the exact depths on them.

When practicable, fishermen or others should be requested to guide the hydrographer to the uncharted shoals which they know. If this is impracticable, an attempt should be made to verify the information from several sources before an extensive search for the shoal is made. It is sometimes difficult to obtain any, or at least exact, position information from fishermen, because they are not willing to divulge the locations of the uncharted shoals which they know.

### *3623. Visual Discovery of Shoals and Dangers*

Where the water is clear, as in the Tropics, under favorable conditions practically all dangers to navigation may be discovered by keeping close watch on both sides of the vessel during the survey. In addition, dangers and shoals may be disclosed by external evidence such as kelp, flocks of gulls, schools of fish, riffles, eddies, upwelling, heaping up of the swell, and breakers.

The most favorable conditions for the discovery of shoals by sight are a very clear sky, a calm transparent sea, and a high sun. If the sea surface is not entirely calm, in order to avoid being bothered by the surface ripples, the area should be searched to leeward. The sun should be high above the horizon, preferably higher than 45°, and should be kept at one's back. Under certain conditions the sun may be reflected from the surface of the water in a way to dazzle and prevent the observer from seeing through the surface.

The observer should station himself at as high an elevation as practicable, preferably in the crow's nest.

If the water is sufficiently clear, shoals and dangers may be readily detected in shoal depths from a coloration differing from that of the surrounding bottom. Rocks, especially if covered with seaweed, appear brown; coral heads and sand shoals appear whitish or light green. Surface reefs and reefs almost awash appear to be yellowish brown from a little distance away. Coral heads covered by about 2 fathoms appear a light bright green, and shoals in depths as great as 8 fathoms appear blue green in contrast with the indigo of the deeper surrounding depths.

*a. From eddies.*—Eddies are produced by a current being disturbed in its progress by a shoal. It should be noted that the mark of the eddy is always downstream from an isolated shoal, the distance depending on the depth of the water and the velocity of the current. Likewise, eddies are more marked the stronger the current and the greater the difference in depth between the shoal and the surrounding bottom. Dangers and shoals are best detected from their eddies during the last of the ebb or the first of the flood tide.

*b. From kelp.*—Where k lp grows it is one of the best indications of dangers because it is generally associated with rocky bottom. The value of kelp in this respect is described on page 2, Alaska Coast Pilot, Part II. Each isolated growth of kelp, even a

FIGURE 61.—Taking sextant angles from an elevated station.

single stalk, must be investigated. In addition to the usual data a statement should be made in the Record as to the value of the kelp for marking the spot; whether the kelp is visible at all stages of tide and at what distances, or whether it tows under so as to be nearly invisible at times. (See also **7864**.)

Thick extensive beds of kelp, especially those bordering the shores, through which it is not practicable to navigate, need not be thoroughly surveyed nor examined. The outer limit of the area must be defined by fixes and soundings, and a few widely spaced lines or scattered detached soundings should be taken throughout the area to give an idea of the general depth. The area should be outlined on the sheet by symbol and contain the legend "heavy kelp, not navigable, not thoroughly surveyed" (see also **367**).

*c. From fish and gulls.*—Schools of fish are habitually found in the vicinity of shoals. In ocean areas, where a shoal might exist, a school of fish seen near the surface in one location should be considered evidence of a shoal and be noted for future investigation. Likewise, flocks of gulls, which feed on the fish, are similar evidence when they are seen circling over and feeding in one locality.

### *3624. Evidence From Air Photographs*

Air photographs of water areas being surveyed often furnish valuable information to the hydrographer. Any variation in the general appearance on the photograph of water areas may mean a difference in depth or character of bottom important enough to be shown on the hydrographic sheet. Such differences in appearance have resulted, upon investigation, in the detection of dangerous sunken rocks between sounding lines previously considered adequate to furnish indications of such dangers. Occasionally, as in flat white sand bottom with numerous patches of grass, the differences appearing in the photographs may be too complicated and unimportant to warrant investigation in detail.

Small spots, scratches, or changes in tone which appear on only one photograph may be due to defects in manipulation or materials of the photographic process. But if a similar difference in the same locality appears in each of two or more overlapping photographs, it is practically certain to indicate differences in bottom or currents. Unless the water is muddy or the water surface too rough, air photographs will show the pattern of shoals or channels in depths to approximately 2 fathoms, and under the most favorable conditions, to much greater depths. A careful study of the photographs of a surveyed area will enable the hydrographer to interpret photographs of similar areas. The indications may vary with the locality from darker rocks or vegetation on shoals in generally lighter colored bottom, to light colored rocks projecting above darker general depths.

The surface of the water as photographed may also indicate areas requiring investigation. Tide rips, swirls, breakers, differences in a regular wave pattern, slicks, and kelp may at times be more readily detected on the air photographs with their elevated view than from the surface.

The spots selected for investigation may usually be transferred to the boat sheet by one of the methods described in **2394**(B) for transferring supplemental stations from photographs. This advance information is particularly valuable if the hydrographer happens to sound in that vicinity when the sea is unusually calm. On boat sheets prepared from photographic surveys (see **7333**), the limits of shoals and channels are indicated by fine dash lines. These are useful in planning the system of sounding lines and development of the area.

If it becomes practicable to have air photographs taken especially to supplement the hydrography, the following conditions are the most favorable: sun behind the camera at an elevation of 40° to 60°, clear sky, sea calm or rough enough to cause breakers, and low tide.

### 363. Bare Rocks and Rocks Awash

Each isolated bare rock and rock awash within the project area, must be located and its height determined by the hydrographer, unless this has been done by the topographer, in which case the hydrographer must verify the data. (See also **782**.) The important rocks of a group or rocky area should likewise be located and determined in elevation.

Where it is practicable to land on such features the location should be determined by a strong three-point fix taken at the rock. Otherwise the rock may be *cut in* from successive positions of the boat, selected so as to give strong intersections at the rock, or may be located by sextant positions taken from the boat when in range with the rock and control stations bearing in several directions.

The height of each rock above the water must be determined as accurately as practicable and the time noted and entered in the Sounding Record, together with the height, for use in reducing the elevation to the plane of reference. If a landing can be made and the sea is calm, the height of a bare rock can be best measured on a staff whose lower end is held at the water's edge, the height being noted on the staff by lining it in with the horizon with the eye at the top of the rock. If it is not practicable to land on the rock the height should be estimated as accurately as possible from a position nearby.

The data relative to bare rocks and rocks awash originating with the hydrographic survey and the topographic survey must be in agreement or be supplemental; any discrepancies between the two surveys must be reconciled before the party leaves the working ground at the end of the season. (See also **3244**, **381**, and **753**.)

Where a rock that has been adequately located by the topographer is passed on a sounding line, a note of this fact shall be entered in the "Remarks" column of the Sounding Record with an estimated distance when the rock is abeam. It should be made clear that these data are not to be used to locate the rock but merely as verification of its existence. Where such a feature is passed close-to without a reference to it, doubt may arise in some circumstances as to whether it actually exists. (See **3353**.)

If air photographs of the area are available they should be carefully examined for evidence of bare rocks and rocks awash and compared with the hydrographic and topographic survey sheets. (See **3624**.)

If bare rocks or rocks awash shown on prior surveys or on published charts are found to be nonexistent, or in different locations, or with different elevations, a full explanation shall be included in the Descriptive Report, with a recommendation as to the charting procedure to be followed.

### 364. Sunken Rocks and Breakers

Where the existence of a sunken rock or other danger is evidenced by breakers and it is impracticable to locate it by a three-point fix or to obtain a sounding on the spot, it must be located by cuts from nearby positions of the sounding boat chosen to form a good intersection at the object, and the depth must be estimated. A statement should be made in the Sounding Record as to the probable accuracy of the estimated depth, together with the time of the observation.

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The conditions under which an area breaks must be noted, at what stage of the tide, and under what conditions of the sea. The distance at which the break is usually visible should also be noted.

Where sunken rocks exist inside a generally foul area they may be symbolized without location so long as the outline of the foul area is accurately located (see also **367**).

### 365. Wrecks and Obstructions

All wrecks and obstructions not afloat should be located and as complete information as practicable furnished. Whether the wreck is totally submerged, visible at all stages of the tide, or visible at some stage of the tide, should be stated and any visible parts of the wreck should be described.

When large pieces of floating wreckage, logs, or other debris, menacing to navigation, are sighted in areas where such obstructions are not commonly encountered, they should be reported immediately by radio to the Commander of the nearest United States Coast Guard District.

Sunken wrecks should be treated as dangers or shoals and the same information should be obtained relative to them. The least depth on a wreck is practically impossible to determine without dragging the area because of the probable existence of masts or other parts of the wreck which one cannot expect to find by ordinary soundings.

### 366. Examination of Shoals

An examination shall be made to determine the least depths on all dangers to navigation and important shoals in the project area. The regular system of sounding lines in the area or a more closely spaced system for development, may locate the position of a shoal within definite limits, but only in rare instances will the least depth be found in this manner, particularly where the area is rocky. The least depth must be found by an intense examination of the limited area in which the shoal is known to exist. This may be accomplished in any one of several ways.

Where the bottom is visible there is no particular difficulty in finding the least depth. If a shoal is small in area and is visible, the sounding boat can be placed above it and the leadline watched to ensure that a sounding is obtained on the peak of the shoal. Where the bottom is not visible, the least depth may be determined either by a system of closely spaced lines over the shoal, by wire drag, by *feeling* with the leadline, or by drift soundings.

Where the investigation for least depth consists of a system of closely spaced lines controlled by visual fixes all of the soundings should be recorded; but for drift soundings and feeling with the leadline, only the least depth found and its position need be recorded (see **3666**). As this is a detached position a check angle must be taken, if practicable.

The character of the bottom on each important shoal must also be determined and recorded.

The examination of the shoals discovered should progress with the systematic survey of the area and all shoals or indications found during a season must be examined before the close of the season. Such work should not be postponed until near the end of the season when stormy weather or other circumstances may prevent the completion of all the work planned.

### *3661. Search for Shoals at Low Tide*

All examinations to discover least depths may be conducted more easily and with more certainty as to results at extremely low tides, except that the survey vessel must not be endangered in doing so. Advantage should be taken of the period of spring tides for this purpose and generally only that period from 2 hours before to 2 hours after low tide.

If there is danger of striking the shoal, the examination should always be made on a rising tide, preferably just after low tide, so that if by accident the survey vessel grounds it can be floated more readily during the rising tide. (See also **361**.) But for the survey of extensive shoal areas it may be advantageous to utilize periods of high tide when the survey vessel may run sounding lines over the area with assurance of not striking or stranding.

### *3662. Systematic Sounding Lines Over Shoal*

To delimit the area within which the least depth is, and often to determine the least depth, the most practical method is a system of closely spaced sounding lines run over the limited area in which the shoal is known to exist. The closeness of the spacing will depend on the character of the area and the type of danger or shoal. In a search for an isolated rock, lines 10 meters apart may be required, while over large shoals composed of sand in which rocks are unlikely, all that may be required is to split the principal system of lines with one or more lines.

If splitting the principal system of lines will not give an adequate development, a new system of lines should be run over the shoal, at an angle of 45° or more to the direction of the principal system.

For a close development the use of ranges is almost essential, and for areas near enough to the coast they should always be used to assist in covering the area closely and economically (see **3142**). Distance angles may be used for the same purpose if more convenient (see **3143**).

### *3663. Examination With the Wire Drag*

When a danger or obstruction is not visible the only positive way of proving the least depth on it is by the use of a drag. In important areas the standard wire drag should be used for such purpose and to disprove the existence of reported dangers and obstructions.

In many cases time can be saved by developing danger indications with the drag. This is especially true where the shoal area is large and is suspected of containing isolated rocks or pinnacles. The wire drag should also be used where the nature of the bottom and the adjacent shore indicates the probable existence of dangers that may have been missed by ordinary sounding.

Any important danger discovered must be cleared with the wire drag within 2 feet of the least depth obtained on it if this is possible. If it is impracticable to clear it by this small margin the reason should be stated in the Descriptive Report.

Unless otherwise directed all wire-drag operations shall be executed in accordance with the requirements of Special Publication No. 118, Construction and Operation of the Wire Drag and Sweep. (See **391**.)

### *3664. Isolated Rocks and Shoals*

An isolated rock or shoal may be found by a system of closely spaced sounding lines and, when found, its slope to the top may be followed by feeling with the leadline. The use of one or two marker buoys is almost essential for this purpose. On arrival at the area one marker buoy should be anchored at the supposed location of the shoal and another held in readiness in the boat for immediate use when the exact location has been discovered. (See **3665**.)

The lines and the soundings along them must be closely spaced for this purpose and if the leadline is used the progress of the vessel must be slow. It is good practice to use two leadsmen, one on each side of the boat.

If there is a current and the leadline is used, the most effective method is to let the boat drift along a series of closely spaced parallel lines to cover the suspected area. The boat should be run into the current until it is up-current from the supposed location of the shoal and on one of the lines to be followed. It is then allowed to drift while the leadsmen sound or feel along the bottom with leadlines until it is down-current from the supposed location of the shoal. It is then propelled up-current again and allowed to drift along the next line, and so on until the shoal is found or the area is covered. When the shoal is found the second marker buoy should be thrown over at once. If practicable the lead which has struck the shoal should be left on the bottom, the leadline being payed out while the boat is propelled upstream to a position vertically above the lead, whence by feeling in the vicinity with the leadline the least depth may be determined.

After the position of the shoalest area has been fairly well determined, a good substitute for the wire drag is to cover the shoal area with drift soundings. Three or more leadsmen may be distributed along the side of the boat, each with two leadlines, one in each hand. The boat is maneuvered upstream from the shoal and turned broadside and allowed to drift over the shoal spot while the area is felt out by all of the leadsmen. If the area is close inshore, ranges should be used to keep track of the courses drifted over. The exact ranges should be noted where the least depth on each line is found. The boat should then be maneuvered upstream and allowed to drift over the shoal again, overlapping the previous area by approximately a half boat length. This should be repeated until the shoal has been entirely covered.

The position of the least depth has now been closely determined and by means of the observed ranges the boat should be anchored at the spot with the least scope of anchor line which will hold. With the leadsmen placed as before the boat is now sculled in an arc around the anchor. The anchor line is then let out a half boat length and the same procedure followed. The operation is repeated until the least depth is found.

The leadlines may be prepared by attaching a float to each a few feet farther from the lead than the least depth expected. Then when the rock is found the leadline may be let go, leaving the lead on the bottom with the float marking the spot. With this as a guide, the least depth can be determined in a few minutes by feeling over it.

### *3665. Use of Marker Buoys*

In the examination of shoals the use of marker buoys is almost essential not only to mark the position of a shoal after it has been found, but also for reference in maneuver-

ing the boat or launch around the area being investigated. A supply of them, the type depending on the area and the purpose for which they are to be used, should always be at hand during the examination of shoals.

In areas where shoals are expected and the control is weak so that it might be difficult to find the shoal again, a marker buoy should always be kept in readiness to be thrown overboard to mark any shoal sounding found during the systematic survey of the area. If there is any likelihood of being unable to find the marker buoy later or it would be uneconomic to revisit the area, the regular sounding line should be discontinued and the examination made at once. Otherwise the examination should be made as soon as practicable because of the possibility of the marker buoy dragging or being lost if it is left for too long a time.

#### *3666. Record of Shoal Examinations*

Where a shoal is examined by sounding along a systematic series of lines, all data should be recorded in the Sounding Record as usual.

Where the shoal is found or the least depth is determined through drift soundings or any other nonsystematic procedure, a full report must be entered in the Sounding Record of the following items when they are not otherwise evident:

(*a*) The method of search used.
(*b*) The length of time spent in the examination.
(*c*) A statement as to whether bottom was visible or not.
(*d*) The apparent area of the top and base of the shoal.
(*e*) The character of the bottom.
(*f*) Whether the shoal is marked by kelp, eddies, riffles, or other visible evidence.
(*g*) Sufficient additional information to enable the reviewer to determine whether the examination was adequate.

### 367. Development of Large Shoal Areas

A large shoal area consisting of sand or mud where it is improbable that rocks or obstructions exist may be satisfactorily developed by a system of closely spaced parallel sounding lines without the necessity for further examination. It must be reasonably certain, however, that the least depth, if it is less than 10 fathoms, has been determined within 2 feet.

Where a large shoal area may contain isolated rocks or rocky elevations a system of closely spaced lines must be run over it to determine the probable location of these, the most important of which must then be separately examined (see **366**). It is not necessary that every rock be examined, but it is essential that the shoalest one be found and the least depth over it be accurately determined. If the shoal area is extensive enough the least depths in several different places should be determined.

Where an extensive foul area exists in an isolated locality where little navigation is expected, such a thorough development is not required. Typical depths should be determined throughout the area and around the periphery, the limits of the foul area being determined accurately. The area may then be outlined on the smooth sheet with a dash line within which appears the legend "foul, not thoroughly surveyed". (See also **7826**.)

### 368. Development of an Offshore Shoal

For the development of areas beyond the limit of visibility of shore signals, survey buoys located with reference to the shore stations shall be established, if practi-

cable, in order that details of the area may be plotted in their proper positions and the area be completely and economically covered. Where this is practicable, the investigation of the shoal area is carried out, using the survey buoys for signals, just as any other similar area would be surveyed. Where this is impracticable, two other methods may be used.

Where an offshore shoal of small area and of shallow depth must be developed from a launch or small boat where three-point fixes cannot be used, a buoy with a tall mast may be anchored with a short scope near the center of the shoal. The height of the top of the mast above the waterline must be known and the method can be used only when the counterweight is heavy enough and the sea calm enough so that the mast remains almost vertical. After the buoy has been located, lines radiating to and from it may be run by compass courses, the distance from the buoy at each fix being determined by measuring the subtended vertical angle between the top of the mast and the waterline (see **3363**). The deviations of the compass must be accurately known. (See also **3365.**)

Where the shoal is extensive and the depths on it are not dangerous, one survey buoy may be anchored at or near its center and located. The area may then be systematically covered with the survey vessel by a series of lines radiating from the buoy, the positions close to the buoy being referred to it by compass bearings and range-finder distances and the positions farther away by bearings and depression angles or by dead reckoning and log distances from the buoy.

To develop closely an offshore area where shore control is visible but is so distant that it cannot be plotted within the limits of a large-scale sheet, *circle* sheets may be used (see section **37**).

## 37. LARGE-SCALE OFFSHORE SURVEYS

In offshore hydrography using three-point fix control it is frequently desirable to develop portions of the area on a larger scale than that used for the general area, as for example, extensive shoals which can almost never be satisfactorily developed on a small scale. Even if a large-scale sheet can be constructed to include the required control stations, it will usually be found that protractor-arm extensions are required, making it difficult to plot positions quickly and accurately. Any distortion of the boat sheet further complicates the problem. But if a sheet of the desired scale cannot be constructed to include the required control stations, the conventional method of plotting three-point fixes certainly cannot be utilized. To obviate these difficulties, *circle* sheets can be used on which fixes can be plotted without the use of a protractor. A wider application of this method is strongly recommended.

Simply stated, the method consists in drawing on the boat sheet or smooth sheet, intersecting systems of arcs of circles, each circle corresponding to the locus of some angle between two control stations. A position is then plotted at the intersection of the loci of the two observed angles, each locus being found by interpolation between the arcs drawn on the sheet.

Although considerable work is involved in placing the arcs on a sheet originally, the ease with which fixes can be plotted and the increased accuracy of the results obtained more than compensate for the time spent, especially where numerous fixes observed to the same stations are to be plotted.

## 371. Derivation of Formulas

In the general consideration of the problem, certain fundamental formulas are necessary. These are derived as follows:

In figure 62, $B$ and $C$ are control stations.

$a$=distance from $B$ to $C$.

$\alpha$ and $\frac{\alpha}{2}$=observed angles from $B$ to $C$.

$A$ and $A'$=centers of circles which are loci of all points where angles $\alpha$ and $\frac{\alpha}{2}$ can be observed.

$d$ and $d'$=$AD$ and $A'D$ respectively—measured along the perpendicular bisector of $BC$.

$c$=radius of circle $BA'C$.

In the circle $BA'C$,

$$d = \frac{a}{2} \cot \alpha. \tag{1}$$

$$c = \frac{a}{2} \operatorname{cosec} \alpha. \tag{2}$$

It can also be shown that,

$$\frac{a}{2} \operatorname{cosec} \alpha = \frac{a}{2} \cot \frac{\alpha}{2} - \frac{a}{2} \cot \alpha. \tag{3}$$

That is, the radius $c$ for any angle $\alpha$ equals the difference between the $d$ distances for $\frac{\alpha}{2}$ and $\alpha$; in other words, $c=d'-d$. Stating the relationship in another way, the arc for an angle $\alpha$ will pass through the center for the arc of angle $\frac{\alpha}{2}$. (See **3751** for application of this relationship.)

In computing the $d$ and $c$ values, a scale factor is introduced so that the results can be measured directly on a 1:10,000 scale meter bar. For any scale, the formula is:

$$\text{Scale factor } (X) = \frac{10{,}000}{\text{scale used}}.$$

Thus, if the scale used is 1:40,000, $X=\frac{1}{4}$.

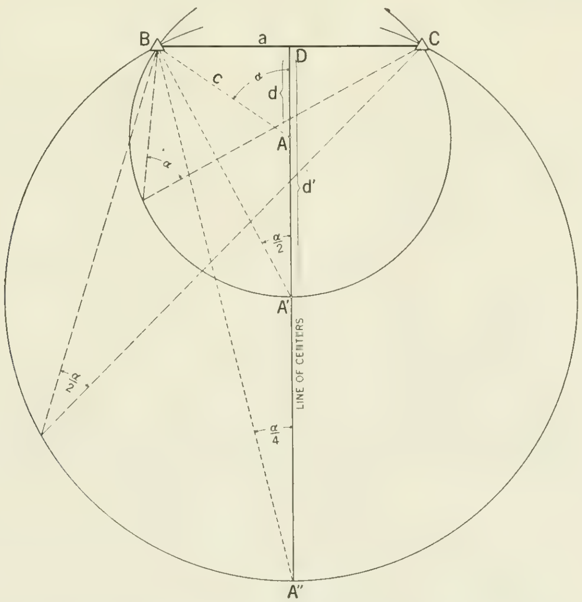


FIGURE 62.—Principle of plotting angles without a protractor.

*Equations* (1) and (2) therefore become,

$$d = X\frac{a}{2}\cot\alpha. \tag{4}$$

$$c = X\frac{a}{2}\operatorname{cosec}\alpha. \tag{5}$$

To facilitate the computations there is included in **964** a table of natural half-cosecants and half-cotangents for angles from 1° to 90°. For larger angles the functions can be derived from this table from the relationship, $f(\alpha) = f(180° - \alpha)$. And since the cotangent of an angle larger than 90° is negative, the $d$ distances along the Line of Centers would be measured above the line $BC$ (fig. 62).

The use of the table and formulas is illustrated by the following example:

The distance between two control stations is 5,000 meters, the scale of the sheet is 1:40,000, and let $\alpha$ be 4°, then substituting in *equations* (4) and (5):

$$d = \frac{1}{4}\times 5{,}000\times 7.1503 = 8{,}937.9 \text{ meters measured on a 1:10,000 scale meter bar}$$

and $$c = \frac{1}{4}\times 5{,}000\times 7.1678 = 8{,}959.8 \text{ meters measured on a 1:10,000 scale meter bar.}$$

A table of the necessary logarithmic functions should be prepared in advance if their use is preferred.

## 372. Preparing Circle Sheets

The problem of preparing circle sheets consists generally in determining the centers and radii of the arcs and drawing the arcs on the sheet. The method to be followed in a given case depends on the relative positions of the two control stations of any system of loci and the large-scale sheet. Five cases may arise. They are:

Case 1. Both stations are off the sheet and the Line of Centers is off the sheet. (See **374.**)
Case 2. Both stations are off the sheet and the Line of Centers is on the sheet. (See **3751.**)
Case 3. One station is on the sheet and the Line of Centers is on the sheet. (See **3752.**)
Case 4. One station is on the sheet and the Line of Centers is off the sheet. (See **3753.**)
Case 5. Both stations are on the sheet and the Line of Centers is on the sheet. (See **3754.**)

Case 1 may be considered the *general case* and the other four cases as *modifications of the general case* and they are so treated in this Manual.

## 373. Preliminary Layout

Irrespective of the conditions encountered or of the method used in preparing the circle sheets, a preliminary layout must first be made on a chart of the locality on which the control stations and the limits of the various sheets to be used are accurately plotted (figs. 63 and 66). This should be done prior to any computation or plotting. The layout is needed in selecting the control stations to be used, if there are more than three to choose from, and as a guide in determining the angles to be computed.

It may be necessary to traverse with the vessel around the area to be surveyed to select the best fix available. The importance of this selection cannot be too strongly emphasized. Signals most likely to be visible under all conditions should be selected as this will often reduce the number of systems of arcs on a sheet and reduce confusion in plotting. The selection of stations is not limited to those constituting a three-point fix, but any two pairs that give good intersecting arcs may be used.

## 374. General Case

### BOTH STATIONS OFF THE SHEET—LINE OF CENTERS OFF THE SHEET

There are two methods of solving the general case: the *graduated perpendicular* method, and the *auxiliary straight-line* method. Both are described and the hydrographer should select the one which best suits his particular conditions.

### *3741. Graduated Perpendicular Method*

#### *a. Preliminary construction*

Before this method can be applied the following preliminary construction is required on the layout sheet (fig. 63):

(1) Erect a perpendicular bisector (Line of Centers) to the line joining two control stations selected for one angle.

(2) With centers on the perpendicular bisector and radii equal to distances to one of the stations (*P* in the figure) four arcs are drawn within the limits of the large-scale sheet, one near the top, one near the bottom, and two approximately equidistant beween the top and bottom arcs.

(3) With a protractor set on any point on each of these four arcs, measure the angle $\alpha$ (to the nearest degree) subtended between the two control stations. In figure 63 these angles are 17°, 19°,


FIGURE 63.—Layout sheet for graduated perpendicular method.

22°, and 25°. Also measure on the layout sheet the maximum range of angles that will be required on the large-scale sheet. This will determine the limiting circles to be drawn. These angles should all be laid off on the Line of Centers so that when construction of the circles is begun, it will require merely an inspection of the layout sheet to place the boat sheet on the drafting table so that the Line of Centers will be within the limits of the table top.

(4) On each of the four arcs select three points, *A*, *B*, and *C*—one near each edge and one near the centerline of the sheet. With a protractor measure the azimuths (to the nearest half degree) between the center for each arc and the three selected points on that arc. (See azimuth line from Line of Centers to point *C* on 25° arc in figure 63.) These scaled azimuths are used later in the computation of the geographic positions of the selected points (see **3741***b*(5)).

This completes the work on the layout sheet. The same procedure is followed for every pair of stations to be used on the survey sheet.

### *b. Computations*

Before the arcs can be constructed on the large-scale sheet the following computations must be made:

(1) Compute the distance and azimuth, by an inverse computation if necessary, between each pair of stations to be used.

(2) Compute the geographic position of midpoint $D$ between adjacent stations.

Where distances between stations do not exceed 25,000 meters and the latitudes are not higher than 15°, the position may be obtained by taking the means of the latitudes and longitudes of the adjacent stations. This gives the position as accurately as it can be plotted.

(3) By means of *equation* (4) compute the $d$ distances along the perpendicular bisector (Line of Centers) from the midpoint $D$ to the centers of the curves for the entire range of curves to be drawn on the sheet. Compute also the radii of the curves ($c$ distances) by means of *equation* (5).

Curves should be drawn to the limits of the sheet, as a fix is often desired beyond the limits of the hydrography. Arcs drawn for every degree above 20° and for every half degree between 10° and 20° usually give sufficient accuracy. For plotting between the arcs small spacing dividers will be found helpful for interpolation.

(4) Compute the geographic positions of the centers for the four arcs selected on the layout sheet (see **3741**$a$(2)).

(5) Compute the geographic positions of the three points ($A$, $B$, and $C$) selected on each of the four arcs on the layout sheet. This is readily done by using the computed radii (see (3) above) and the assumed azimuths as scaled from the layout sheet (see **3741**$a$(4)).

### *c. Construction of arcs*

When the graduated perpendicular method is used, the physical construction of the arcs on the large-scale sheet can be accomplished in one of the following three ways:

1. With beam compass.
2. By computation.
3. With three-arm protractor.

1. *With beam compass.*—In this method, a special beam compass about 8 feet long is required. This will permit drawing curves with a 30-mile radius on a 1:20,000 scale sheet and will probably meet most requirements. The beam should be of sturdy construction to eliminate sag. A beam made of well-seasoned wood in the form of a 2-inch T in cross section has been found to have the required amount of rigidity. Two beams spliced together have been found unsatisfactory. A drafting table large enough to accommodate the survey sheet and the Line of Centers is necessary.

A projection is first constructed on the survey sheet. It is then placed on the drafting table in such a position that none of the centers is beyond the limits of the table top. This can be easily done from an inspection of the layout sheet and by determining the direction of the Line of Centers and its approximate distance from one of the edges of the survey sheet. The latter is then thumbtacked in position. A piece of boat-sheet paper is then tacked on the drafting table where the Line of Centers is expected to fall. The width of the boat-sheet paper will allow for the approximation in position.

A narrow strip of boat-sheet paper slightly longer than the radius of the longest arc to be swung is secured to the table for use in measuring long distances. Intervals of 10,000 meters (the length of the 1:10,000 scale meter bar) are laid off along a straight line on the strip of paper and marked 0, 10,000, 20,000, 30,000, etc. A small piece of celluloid is fastened over the zero point to prevent excessive wear from the repeated measurements necessary from this point (see **7631**). In laying off the lengths of the radii, the increments from the 10,000-meter intervals should first be plotted and then the total distances set on the beam compass.

The three points, $A$, $B$, and $C$ (fig. 63), on each of the four arcs on the layout sheet are plotted on the survey sheet by their geographic positions (see **3741**$b$(5)). With these points as centers and with the $c$ values as radii (see **3741**$b$(3)) arcs are swung on the strip of paper on which the Line of Centers

will fall. The intersection of the arcs from each group of three points ($A$, $B$, and $C$) will be the center for the arc through those points. A straight line drawn through the four intersections will define the Line of Centers. An additional check on the accuracy of the construction is to compare the distances between the four centers graphically determined with the computed $d$ values (see **3741***b*(3)). Any discrepancy should be adjusted in relation to the four points established by the construction work.

The centers for all arcs required on the sheet are then plotted on the Line of Centers from the computed $d$ values, each measurement being made from the nearest plotted center. It will be found convenient to establish an initial point of some even thousand meters near each of the centers laid down by construction, to facilitate subtracting between adjacent distances between centers.

From the centers thus determined arcs are drawn on the survey sheet, using the computed $c$ values as radii. A check is obtained if the arcs pass through the 12 computed points on the survey sheet. A further check is obtained if the arc corresponding to a given angle passes through the center of the arc of half that angle. (See *equation* (3) in **371**.)

In using a long beam compass best results are obtained by applying light pressure at the fixture directly over the pen, the other fixture being lightly held in place at the circle center. Pressure applied at any other part of the beam may cause variable flexure while drawing the arcs.

For quick identification in the field, it will be found helpful to use colored inks for the arcs. In some cases it may be desirable to use different colors for the different systems, while in others it may be more helpful to use colors to designate the angular values, such as black for whole degrees, blue for half degrees, and other colors for smaller intervals if used. (See **735** for instructions for inking arcs on smooth sheets.)

2. *By computation.*—There may be cases where it is preferable to compute the rectangular coordinates of points on the arcs and then draw them in with the aid of standard curves. Such a method will be found useful where the radii of the circles are too long for the beam compass at hand or where not too many circles are required.

When this method is used, the procedure up to the point of constructing the arcs is the same as heretofore described, except that all the arcs that will be required on the survey sheet must be drawn on the layout sheet, rather than only four. Three points are selected on each arc as before, but the geographic position of only the middle point ($B$ in fig. 63) need be computed, only the azimuths (scaled) of points $A$ and $C$ being used. The procedure is as follows:

(*a*) Compute the geographic positions of the intersections of the radii passing through the selected points at each end of an arc ($A$ and $C$ in fig. 63) with the tangent to the arc at the selected middle point $B$. This is readily done by using the scaled azimuths of the radii and the computed geographic position of the point $B$ (see **3741***b*(5)). Plot the tangent line on the sheet.

(*b*) Considering the radius to the selected middle point on the arc as the $Y$-axis and the tangent line as the $X$-axis, the rectangular coordinates of points on the circle passing through the origin of the system are derived as follows:

In figure 64,

$DB$ = azimuth line from center of circle to selected middle point, or the radius $c$ of the circular arc $BR$.
$BP$ = the normal line.
$BS$ = $x$-coordinate of point $R$.
$SR$ = $y$-coordinate of point $R$.
$RP$ = an extension of radius $DR$.
$\theta$ = the angle $RDB$ or $PRS$.

Then,

$$\text{Tan } \theta = \frac{BP}{c}$$

and $$x = BP - SP = BP - y \tan \theta.$$
and $$y = c - c \cos \theta.$$

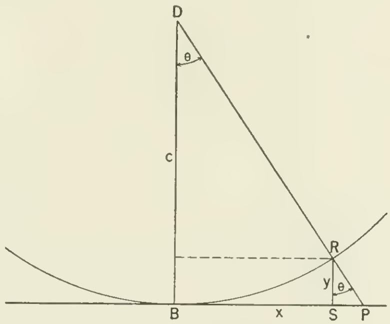

FIGURE 64.—Construction of the arcs from rectangular coordinates.

Assigned values of $BP$ are entered in the above formulas and the corresponding values of $x$ and $y$ are solved by logarithms. It is unnecessary to find the angular value of $\theta$, but simply the value of the cosine corresponding to the tangent of the angle.

3. *With three-arm protractor.*—This method of drawing the arcs is not strictly a part of the "Graduated Perpendicular Method" since all the steps included in that method are not necessary for its use, and as will be seen it is also part of the "Auxiliary Straight-Line Method" (see **3742**).

When this method is used, the preliminary construction on the layout sheet is accomplished as before (see **3741**$a$), except that enough arcs should be drawn to permit an accurate graphic interpolation for intermediate arcs as explained below. The computation, however, is greatly simplified. The computation required in **3741**$b$ (steps (2), (3), and (4)) can be omitted in this method since the geographic position of a point $C$ (fig. 65) on a locus of an angle $\alpha$ can be computed from the triangle $CMP$, the angle $MPC$ being scaled from the layout sheet.

In figure 65, $A$ and $C$ are two points on the locus of angle $\alpha$ and near the margins of the survey sheet. (These correspond to the selected points $A$ and $C$ in fig. 63.) The angle $\alpha$ is the observed angle

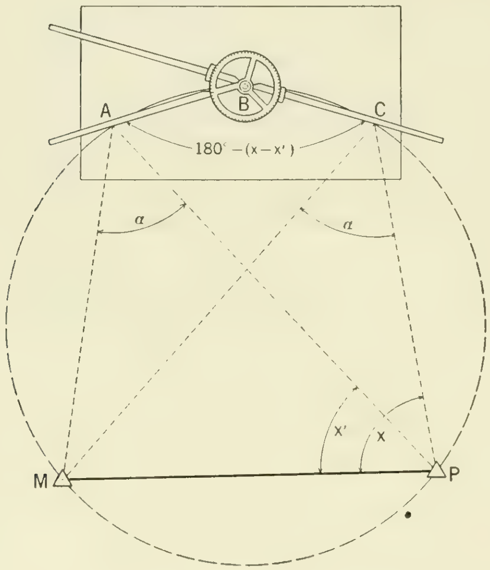


FIGURE 65.—Drawing the arcs with the use of a protractor.

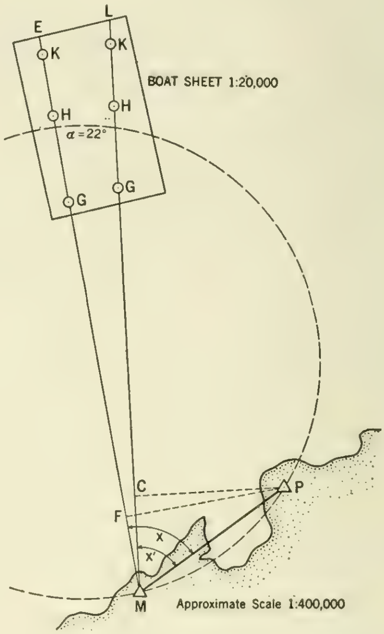


FIGURE 66.—Layout sheet for auxiliary straight-line method.

between the two triangulation stations $M$ and $P$, and the angles $x$ and $x'$ are from the scaled azimuths from the layout sheet. The geographic positions of $A$ and $C$ are computed by the method noted above and the points are plotted on the survey sheet.

The angle at $B$ equals $180° - (x - x')$ and this holds true for any point along the arc $AC$. Therefore, this angle is set on a metal protractor, using the movable arm that can be closed to a zero reading. Two pins are firmly set at the plotted positions $A$ and $C$. A pencil is centered in the protractor and the arc is drawn by moving the protractor along, with the arms sliding against the pins. The portion of the arc that falls beyond points $A$ and $C$ is plotted with the angle $x - x'$ set on the protractor.

If the distance between $A$ and $C$ is too long to permit sliding the protractor very far from the center of the sheet, then use is made of the geographic position of point $B$ (see **3741**$b$(5)) for pivoting the protractor arm. In such case, however, the angle set on the protractor is 180° minus the difference in azimuths between the line to $B$ and the line to $A$ or $C$ depending on which part of the arc is being drawn.

The same procedure is followed to lay off the other arcs on which points have been computed. Intermediate arcs can be laid out in a similar manner by constructing graphs of the rate of change of the angle $\alpha$ between each of the computed arcs and plotting scaled locations of intermediate positions corresponding to $A$, $B$, and $C$. Graphs for the rate of change of the protractor angle are also needed for use in determining the protractor setting for the intermediate arcs.

### *3742. Auxiliary Straight-Line Method*

In this method use is made of two auxiliary straight lines graduated on the principle of the graduated perpendicular and furnishing points through which the arcs may be

drawn with the aid of a three-arm protractor. The method is adaptable for use without the advance drawing of the arcs on the large-scale sheet since, by means of the graduated auxiliary lines, the position of the vessel may be plotted from the loci of the two observed angles. This may be advantageous where limited offshore investigations are required, and cannot be done with the graduated perpendicular method.

### *a. Preliminary construction*

(1) On the layout sheet (fig. 66), draw two auxiliary straight lines $ME$ and $ML$, through one of the stations to be observed on, making angles $x$ and $x'$ with line $MP$ and located on the side of the line where the arcs are to be constructed. The azimuths of these lines are scaled to the nearest degree.

(2) From $P$, the other station to be observed on, erect perpendiculars to the two auxiliary lines, intersecting them at points $F$ and $C$. Select three well-distributed points $G$, $H$, and $K$ on each auxiliary line and scale their distances to the nearest 1,000 meters from points $F$ and $C$.

### *b. Computations*

(1) With the scaled azimuths and distances compute the geographic positions of $F$ and $C$ and of the three selected points ($G$, $H$, and $K$) on each line.

(2) Compute the distances $PF$ and $PC$, and from *equation* (4), $d=X\frac{a}{2}\cot\alpha$, and the table of natural half-cotangents in **964**, compute the distances along $FE$ and $CL$ for various angles $\alpha$ to cover the entire range of curves to be drawn, $a$ in the formula being equal to $2PF$ and $2PC$. These graduations are points where the auxiliary straight lines intersect the various arcs passing through $M$ and $P$.

The truth of this proposition is demonstrable from a consideration of figure 67.

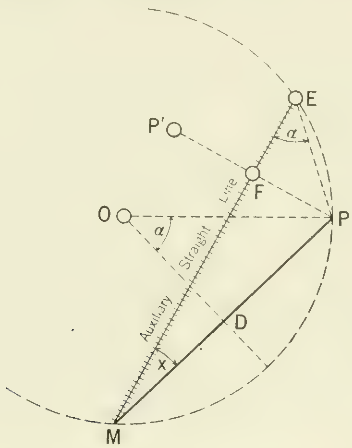


FIGURE 67.—Principle of auxiliary straight-line method.

In the figure, $DO$ is the Line of Centers for stations $M$ and $P$, and $ME$ is an auxiliary straight line making an angle $x$ with $MP$. $O$ is the center of the circle which is the locus of all points where angle $\alpha$ is observable and which intersects the auxiliary line at point $E$. If, from station $P$, a perpendicular $PP'$ is drawn to $ME$ making $FP'=FP$, then $ME$ is the Line of Centers for circles passing through $P$ and $P'$ and by *equation* (1) in 371,

$$FE=\frac{PP'}{2}\cot\alpha=2PF\left(\frac{\cot\alpha}{2}\right)$$

Therefore, graduations along the line $ME$ for various angles $\alpha$ will be points on the arcs of corresponding angular values and which pass through stations $M$ and $P$.

### *c. Construction of arcs*

(1) On the large-scale sheet plot the three selected points $G$, $H$, and $K$ on each of the auxiliary lines from their computed geographic positions ($b$ (1) above), and draw straight lines through them.

(2) Plot the graduations on the auxiliary straight lines from the values obtained in $b$ (2) above. To do this the geographic position of one of the graduations on each of the auxiliary lines must first

be computed from its azimuth and distance (see $a(1)$ above), and from that point the other graduations may be plotted.

(3) The construction of the arcs is accomplished as in the three-arm protractor method by setting on the protractor the angle corresponding to $180°-(x-x')$ and making the two arms pass through corresponding graduations on the auxiliary lines. The center of the protractor will be a point on the arc sought. If portions of the arc to be drawn are outside the auxiliary straight lines then the angle set on the protractor will be $(x-x')$, that is, the angle between the two auxiliary lines. (See **3741**$c$(3).)

It is to be noted, of course, that in this method it is not absolutely necessary that the arcs be drawn on the sheet as is the case in **3741**. The vessel's position may be plotted by swinging the loci of the observed angles. This may be advantageous in certain field investigations or in plotting the smooth sheet.

## 375. Modifications of the General Case

The problem is simplified where the Line of Centers is on the sheet or where one or both the stations are on the sheet.

### *3751. Both Stations off the Sheet—Line of Centers on the Sheet*

By referring to the layout sheet, select three points, a suitable distance apart, within the limits of the survey sheet being prepared and close to the perpendicular bisector of the line joining two of the control points. Their distances to $D$ (fig. 62) are roughly scaled from the layout sheet and distances chosen to the nearest 1,000 meters. Using Form 27, Position Computation Third-Order Triangulation, the geographic positions of the selected points are computed from point $D$ along azimuth $DB-90°$ (fig. 62). A straight line is drawn through these points for the entire length of the survey sheet. This is the Line of Centers. Where only a portion of it falls within the limits of the large-scale sheet, it can be extended some distance beyond and onto another strip of paper by means of a straightedge; or it may be feasible to construct a projection to include the entire Line of Centers and then, after the arcs are constructed, cut off the unnecessary portion. If the latter method is used, points near the extreme limits of the line should be computed.

Distances along the Line of Centers and the radii for the various arcs to be drawn on the sheet are computed as described in **3741**$b$(3). These distances are plotted from the nearest computed point, so that practically all distortion along the Line of Centers is eliminated.

Select a point on one of the arcs near the center of the work and compute its geographic position. This is readily done from the corresponding computed center, the computed radius, and an assumed azimuth. A comparison of the scaled and computed radii will determine the distortion correction (if any) to be applied to the rest of the computed radii.

The required arcs are drawn by any of the methods described in **3741**$c$.

Under special conditions computations of the radii may be eliminated even where both the stations are off the sheet. For example, if points $A$ and $A'$ (fig. 62) on the perpendicular bisector fall within the sheet, then the locus of the angle $\alpha$ can be plotted from the relationship given in *equation* (3) in **371**, namely, that the radius of the locus of angle $\alpha$ is equal to the distance from $A$ to $A'$ on the Line of Centers.

### *3752. One Station on the Sheet—Line of Centers on the Sheet*

This is a modification of the above case. Since one of the control stations lies within the large-scale sheet, the radii for the various arcs need not be computed but can be scaled graphically from the plotted centers and the plotted station.

### *3753. One Station on the Sheet—Line of Centers off the Sheet*

This condition is best treated by applying the principle of the "Auxiliary Straight-Line Method" (see **3742**). The same procedure is followed as described there, except that only one auxiliary line is required and it is drawn from the station that falls off the large-scale sheet. The auxiliary straight line is plotted on the large-scale sheet and graduated as before. The arcs are drawn with a three-arm protractor by setting off the angle $x$ (fig. 67) on the protractor and making the two arms pass through the station

plotted or the sheet and the various points of graduation. If the arc to be drawn is within the angle made by the auxiliary line and the line between the stations, then the angle to be set off on the protractor is $(180°-x)$.

### *3754. Both Stations on the Sheet—Line of Centers on the Sheet*

This is the simplest case of all and is for the most part a graphic solution. The radii of the arcs will usually be of such lengths that construction with a beam compass will be feasible.

Referring to figure 62, the distance $a$ between the stations is determined by scaling from the large-scale sheet and the midpoint $D$ is plotted. Erect a perpendicular (Line of Centers) at this point, and by means of *equation* (4) in **371** compute the $d$ distances along this perpendicular for the entire range of arcs to be drawn on the sheet. Where the centers for the arcs to be constructed are at a considerable distance from the midpoint in relation to the distance between the stations, then the Line of Centers should be determined as described in **3751**.

The centers can also be determined graphically by setting the angle $\alpha$ on a protractor and with its center on the Line of Centers and one arm in coincidence, shifting it along the Line until the other arm passes through one of the control stations. Or the locus of $2\alpha$ can be plotted and its intersection with the Line of Centers obtained.

The distance from each of the centers thus determined to either of the stations will be the radius of the arc to be described.

## 376. Various Methods of Use

When surveying an area with a *circle* sheet it will be of great help to run the sounding lines parallel to one system of arcs. This is described in **3143.** The ease and speed with which positions can be plotted will be advantageous under many conditions. It is even possible to cover a shoal thoroughly with evenly spaced lines without plotting one position while sounding. Furthermore, it is usually possible to tell if a change in course is necessary as soon as the angles are taken and before the position is plotted. This method of surveying also permits the selection of stronger fixes, since stations beyond the limits of the sheet can be utilized.

In making large-scale offshore surveys by this method, the small-scale sheet (preferably an aluminum plate) on which all the control stations are plotted, should be kept at hand, so that if one or more of the objects, for which systems of arcs have been constructed, become momentarily obscured, other stations can be utilized for an occasional position, which is plotted on the small-scale sheet and then transferred to the circle sheet.

The method can also be used advantageously wherever the stations are so distant that they are near the ends of the protractor arms, and it is the only satisfactory way to plot closely spaced lines using distant signals. Under such conditions the three-arm protractor is unsatisfactory because of the errors due to the limitation of the protractor and the distortion of the sheet. It is impossible to verify such a sheet, for the same position will not plot in the same place after the sheet has been subjected to any atmospheric changes.

The method also has application in making enlargements of areas originally plotted at a small scale where photographic enlargements are not sufficiently accurate In such case a circle sheet is constructed by one of the methods described above and the positions are plotted directly from the angles in the Sounding Record.

## 38. CONTEMPORARY OPERATIONS

In conjunction with each hydrographic survey certain contemporary operations must be performed and certain data obtained and noted which are not strictly related to sounding. Those which are the responsibility of the Chief of Party and the survey party generally, but which may not necessarily be performed by the hydrographic party, have been described in chapter 1—but those which should be performed by each hydrographic party are described in this section.

### 381. Shoreline by Hydrographer

In conjunction with a survey of the inshore waters adjacent to the shoreline it is incumbent on the hydrographer to see that the necessary shoreline information to accompany the hydrographic survey is available. The high-water line and the topography offshore from it are the most important parts of the topographic information obtained during a hydrographic survey.

The hydrographic party shall verify the correctness of the topographic detail falling within the limits of the hydrographic survey. When both the topographic and the hydrographic survey are made in the same season under the direction of the same Chief of Party, it shall be his duty to see that any discrepancies between the two surveys are investigated in the field and that information common to both is identical.

Where the contemporary topographic survey has been made in a previous season or under a different Chief of Party, the hydrographic party will be responsible for the revision of the topography if any changes have occurred or if any discrepancies are found therein.

Complete notes relative to topographic information obtained by the hydrographic party and all three-point fixes, sextant cuts, and measured or estimated distances shall be recorded in the Sounding Record. The Descriptive Report for the hydrographic survey shall explain in considerable detail the revision of any shoreline, the methods used by the hydrographer to locate it, and the apparent reason necessitating the change. (See also **3244**.)

#### *3811. Shoreline Revision*

Where there has been a contemporary topographic survey either by planetable or from air photographs, the results of which are available prior to the hydrographic survey, the shoreline and all topographic details offshore therefrom shall be transferred accurately to the boat sheet in order that the hydrographer may verify the completeness and accuracy of these data during his sounding operations. Any shoreline data which are found to be inaccurate, or where appreciable accretion or erosion has taken place, shall be corrected and shown on the boat sheet by a broken or solid red line, depending on the accuracy of location (see **753**), accompanied by appropriate notations of the general method used to determine the position of the revised shoreline.

#### *3812. Sketched Shoreline*

Where no topographic survey of the area is available and a contemporary one is not contemplated or where the only information available is from an entirely inadequate reconnaissance survey, the hydrographer should locate by carefully estimated or measured distances all the important features of the shoreline in connection with his hydrography. This may be done from a series of three-point fixes taken close to the

shore specifically for this purpose. From each of these fixes, sextant cuts (preferably three to each point) may be taken and rangefinder distances measured to any recognizable features along the shoreline, the intermediate shoreline being sketched in. The necessary angles and data can often be conveniently obtained in connection with the hydrography by stopping the boat temporarily at the inshore end of each line of soundings. The results of course are inadequate for charting on a large scale, but on small scales where minor detail is usually generalized the results will give a reasonably accurate portrayal.

In areas such as the Aleutian Islands, Alaska, heavy ocean swells may sometimes prevent the topographic party from landing along certain parts of the coastline. If, toward the end of the season, an inshore hydrographic survey has been completed, but the corresponding topographic survey has not, the shoreline should then be sketched from a launch for temporary use in charting. The topographer or the hydrographer takes the boat sheet in the launch and cruises off the shore at an appropriate distance where he can locate his position by strong three-point fixes from the hydrographic stations previously located by cuts and which are plotted on the boat sheet. Additional points on shore are then cut in from the launch, and the shoreline between the points carefully sketched. Such shoreline shall be shown on the boat sheet by a dash line inked in black.

This method of locating the shoreline and offshore topographic details should be used only as a last resort and then only for areas of relative unimportance. An adequate report shall be made as to why the topographic survey was not accomplished, and a statement shall be included as to the probable accuracy of the result by these substitute methods.

### 382. Form Lines From the Ship

Form lines to represent the topographic relief are an important part of a chart, for in piloting the mariner determines his position from those objects he can identify. Consequently, when surveying in an uncharted area, the Chief of Party should see that topographic features of value to the mariner are located as far inland as practicable. This is particularly applicable to the rugged coastal areas of the United States, the Philippines, and Alaska where many conspicuous mountains, hills, and ridges bordering the shoreline lie beyond the limits of the standard 1:10,000 and 1:20,000 scale topographic sheets.

During an ordinary topographic survey of the shoreline, the topographer is frequently limited to cuts to unimportant points on the slopes of minor hills and ridges which rise abruptly from the shoreline. In an effort to supplement the planetable topography with sextant cuts from offshore, it is often found that the desired features lie beyond the inshore limits of the sheets, or that the positions from which satisfactory cuts to such features must be obtained are beyond the offshore limits of the sheets.

Sheets for form lines only, constructed at scales one-half to one-fourth those of the regular topographic sheets, can usually be laid out so that their limits will include all topographic features which are of greatest value to the navigator and at the same time include the offshore water area from which satisfactory cuts may be obtained.

Form lining from the ship can be accomplished simultaneously with the ship hydrography and without any interference with it. The only additional personnel required are sextant observers, and in most instances one is sufficient. The cuts should be recorded in the regular Sounding Record (see **248**) with their respective hydrographic position numbers for plotting at a later date. It is not necessary to stop the vessel to obtain sextant cuts, but advantage should be taken of any stops (for vertical casts, serial temperatures, lowering or hoisting launches, etc.) to obtain

cuts if the locations are advantageous. When the vessel is underway, each cut must be *marked* simultaneously with its corresponding fix. Vertical angles can be measured a few seconds later without affecting the elevations, especially when the course parallels the coast. Heights of trees on hills, ridges, and mountains shall be estimated in order that the elevations may be reduced to ground elevations. On the form-line sheets the elevations of the trees shall be shown in parentheses alongside the ground elevations.

Various points on the slopes and mountainsides should be cut in and vertical angles measured to them in order to control the form lines. The interval between form lines shall be governed by the scale of the form-line sheet and the type of topography; it should show clearly the general formation of the relief and should naturally be smaller for less rugged terrain.

Three or more sextant cuts forming a good intersection must be obtained to locate each object; vertical angles at two of these cuts will be sufficient if the computed elevations check within 10 feet. If the cuts are taken intermittently during an extended period of time so that there might be doubt as to the identity of an object, a vertical angle should be observed and recorded with each cut to serve as additional identification.

Illustrated are tabular forms for abstracting the "observed data" and for the "computation of elevations" which shall be included in the Descriptive Report to accompany a form-line sheet compiled from sextant cuts observed from a vessel.

In the "observed data" form it is to be noted that the vertical angle, column 5, is always measured from the waterline at the shore. In column 7 is listed the correction for tide with reference to *mean high water,* which is usually to be subtracted from the observer's height of eye above the water (column 6) to obtain the height of the eye above mean high water (column 8). The required tide correction in column 7 may be obtained from the Coast and Geodetic Survey Tide Tables; it is the difference between the predicted tide for the time of observation and the "mean range of tide," except when the predicted tides are *minus,* in which case they are added to the mean range of tide.

In the "computation of elevations" form, the various steps are self-evident with the possible exception of column 6, "correction for dip," and column 10, "curvature and refraction correction." The correction for dip is always subtracted from the observed vertical angle. The combined curvature and refraction correction is always added to the computed elevation of the object (column 9).

*Form Lines*

[OBSERVED DATA]

Day letter: A

Sheet No. T–4240 Locality: Bumble Bay Date: 7/14/40

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Time | Position number | Position angles | Cuts | Vertical angle | Height of eye above water | Tide with reference to MHW | Height of eye above MHW | Estimated height of trees |
| hr. mi. | | ° ′ | | ° ′ | *Feet* | *Feet* | *Feet* | *Feet* |
| 10:32 | 1 | Cape 36 25<br>Draw<br>Part 57 10 | Part-Thumb Pk. 24° 32′ | 6 52 | 22 | −4 | 18 | 60 |

*Form Lines*

[COMPUTATION OF ELEVATIONS]

Sheet No. T–4240 Locality: Bumble Bay

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Object | Position number | Height of eye above water | Scaled distance to shoreline | Observed vertical angle | Correction for dip | Corrected vertical angle | Scaled distance to object | Computed elevation | Curvature and refraction correction | Height of eye above MHW | Height of trees | Elevation of ground | Mean elevation |
| | | *Feet* | *Naut. miles* | ° ′ | *Minutes —* | ° ′ | *Meters* | *Feet* | *Feet* + | *Feet* + | *Feet* — | *Feet* | *Feet* |
| Thumb Peak | 1A | 22 | 1. 5 | 6 52 | 9 | 6 43 | 5574 | 2154 | 7 | 18 | 60 | 2119 | ----- |
| Lat | 20A | 19 | 2. 5 | 4 37 | 6 | 4 31 | 8305 | 2152 | 15 | 14 | 60 | 2121 | ----- |
| Long | 17C | 18 | 2. 0 | 5 17 | 6 | 5 11 | 7230 | 2152 | 12 | 13 | 60 | 2117 | 2119 |

Observed data are entered in columns 1, 2, 3, 5, 11, and 12.
Data entered in columns 4 and 8 are measured from the form-line sheet.
Values in columns 6 and 10 are from tables 7 and 4, Topographic Manual.
Values in column 9 are computed on hypsograph, or by using table 3, Topographic Manual, from values in columns 7 and 8.
Values in column 13 are algebraic sums of columns 9, 10, 11, and 12.

## 383. AIDS TO NAVIGATION

The positions and characteristics of all aids to navigation in the project area must be accurately determined, and the dates of the determinations given. (See also **784.**)

It is important that the dates of location or visitation be a matter of record insofar as the items under this heading are concerned. This is especially important in connection with floating aids to navigation for at the time of the location the aid may have been temporarily off station and may have been replaced on its correct station by the United States Coast Guard within a short time after it was located.

Landmarks for charts are considered in **155**, and the requirements for objects for use in locating aids to navigation are given in **1551**.

### *3831. Fixed Aids to Navigation*

All fixed aids to navigation established by the United States Coast Guard should be located by triangulation if their geodetic positions are not already available or if the aid has been moved in position or rebuilt since the date of the previous determination. Where for any reason it is impracticable to locate one or more fixed aids by triangulation, a substitute method shall be used, but the determinations shall be such that no appreciable plottable error will result. In projects where there are numerous minor beacons whose positions are subject to frequent change the project instructions may specify that these may be located by methods other than triangulation. If compliance with the instructions requires an apparently unjustified amount of work, the Chief of Party should inform the Washington Office of the facts, recommending an amendment to the instructions. (See also **7841.**)

The positions of all fixed aids located should be reported on Form 567, Landmarks for Charts.

### *3832. Floating Aids to Navigation*

The positions of and depths at all floating aids to navigation in the project area shall be determined during the hydrographic survey. Inshore floating aids should be

located by three-point fixes at the aids, wherever practicable; cuts are not satisfactory, but where they have to be used all cuts to one aid should be taken in a short interval of time so there will be less likelihood of a change in the direction of the current affecting the position of the aid. Offshore aids to navigation beyond the visibility of shore signals should be accurately located by R.A.R. if that method of control is being used in the hydrographic survey. (See also **7842**.)

Where a marker buoy is maintained near an aid to navigation the positions of both shall be determined.

If a floating aid to navigation is found to be off station, the fact should be promptly reported to the Commander of the nearest United States Coast Guard District. If its station is found to be unfavorably located for the purpose for which it was intended, its position and the facts should be reported to the Coast Guard and to the Washington Office. The station of a floating aid is its position on the largest-scale chart of the area. Any recommendations, based on the new hydrographic survey, for additional aids to navigation or for more desirable stations for existing aids, should be reported in writing to both offices as soon as practicable, with a photostat or tracing of the boat sheet.

Reference shall be made in the Descriptive Report to any reports which have been made to the Coast Guard relative to floating aids to navigation.

Refer to **1551** for objects which are to be located for the use of the Coast Guard.

### *3833. Azimuths of Ranges*

The azimuths of all light and beacon ranges maintained by the United States Coast Guard for use in navigation in the project area must be accurately determined. Any that are not determined by triangulation must be determined by the topographer or the hydrographer.

The topographer shall determine azimuths of ranges by actually setting up the planetable at an accurate location on each range at a considerable distance from the front range, the resulting azimuth line being drawn on the sheet as a long line from which the azimuth can be accurately scaled.

Where the azimuth is determined by the hydrographic party the survey vessel shall be placed on the range at a comparatively long distance from the front range where a strong three-point fix and check angle can be observed. Where a check angle is impracticable, two three-point fixes at different locations on the range shall be observed. The azimuth of a range established for use in crossing a bar shall be determined from a position on or outside the bar. The sextant fixes must be recorded in the Sounding Records and indexed. From the accurately plotted positions the azimuths of the ranges are to be scaled by protractor and noted along the range lines on the smooth sheet. (See also **356**.)

### *3834. Nonfederal Aids to Navigation*

Aids to navigation which are established privately or by State or local governments and for which the Federal Government is not responsible, shall be located by the hydrographic party and their positions shall be shown on the smooth sheet, but the status of these aids shall be made clear on the sheet and in the Descriptive Report. The Descriptive Report should state the purpose of the unofficial aids to navigation and the date of their establishment, the agency or person who established them, and whether or not they are maintained, if these facts can be ascertained.

### *3835. Broadcasting Stations*

Commercial broadcasting stations near the coast often have practical value in navigation for use as radiobeacons. Those within the project area should be considered, their value to navigation should be investigated, and those of importance should be accurately located and reported as aids to navigation on Form 567.

### *3836. Clearances*

It is essential that the actual clearances above mean high water of all bridges, cables, and telephone or telegraph lines be accurately known. The clearances of bridges are generally listed in the "List of Bridges Over the Navigable Waters of the United States" published by the United States Corps of Engineers. The data given in this publication should be verified in the field by actual measurements and the proper reports made—if discrepancies are found they shall be fully discussed. The clearances of bridges not listed in the above publication and the clearances of any other overhead obstructions over navigable waters shall be determined by the field party and the data shown on the smooth sheet and included in the Descriptive Report. (See also **7846**.)

The shore ends of all submarine cables shall be located and shown on the sheets (see **7847**).

## 384. Character of the Bottom

In all hydrographic surveys, the character of the sea bottom shall be determined at frequent and regular intervals throughout the project area to meet the needs of navigation and for other purposes. This applies particularly to harbors and anchorages and in all depths where vessels may anchor.

Data on the character of the sea bottom are of value to the mariner in choosing the most suitable place to anchor, where he may expect to find the best holding ground, and what areas are free of rocks. In some instances, bottom data may still be helpful to him in determining his position, although generally their value for this purpose has decreased because of the increasing use of echo-sounding apparatus in navigation. They are of value in connection with dredging operations in harbors and channels and for any underwater construction. Fishermen utilize such information in selecting places where fish are likely to congregate and in avoiding types of bottom which may damage their nets or equipment. And for the students of the earth sciences, bottom data secured in deep water add to the knowledge of that part of the globe covered by water.

### *3841. Methods of Determination*

Knowledge of the character of the bottom is obtained in two ways; first, by bringing to the surface for examination a specimen or sample of the bottom material; and second, by determining the consistency of the bottom material by the feel of the leadline.

There are two general methods for bringing samples to the surface. The more usual of these is by filling a cup-shaped depression in the bottom of the sounding lead with tallow or soap to which a specimen of the bottom material adheres when the lead strikes the bottom (see **4664**). For types of bottom material which will not adhere to the lead, a specially devised snapper with two spoon-shaped jaws closed by a spring is used (see **4761**). In oceanographic work special instruments which dig out and retain a comparatively large core are used (see **476**).

Each method has its own advantages depending on the depth and the character of the bottom. Fine sand will adhere readily to an armed lead, but is likely to be entirely washed out from a snapper, especially if small pebbles or shells are mixed with the sand and are caught between the jaws, holding them partly open while being hoisted to the surface. Soft mud will scarcely adhere to an armed lead at all, but an excellent sample of it may be obtained by the use of a snapper.

Neither the armed lead nor the snapper will secure specimens of a rocky bottom and the best possible indications of this are the feel of the leadline after the lead strikes the bottom and abrasions which may be found on the bottom and sides of the lead.

It must be realized that the specimen obtained on an armed lead is from the surface layer of the bottom, which may be of very different character from that immediately beneath.

In addition to an examination of the specimens brought to the surface, leadsmen and sounding-machine operators must be taught to gage the consistency of the bottom material by feeling through the leadline or the wire the way in which the lead strikes the bottom.

The data on bottom characteristics determined during the sounding must be supplemented by examinations of the material brought up on the flukes of the anchor or on buoy anchors and these data should be recorded in the Sounding Record with their positions given as closely as known.

### *3842. Frequency of Bottom Characteristics*

When sounding with a handlead, the character of the bottom should generally be determined on every fixed position and must be determined at least once on each page of the Sounding Record. In harbors, anchorages, and channels the coverage should be more complete than is necessary elsewhere. Along the open coasts and in large bays and similar areas where tests have indicated that a sameness of bottom material is to be expected, a lesser number is required.

An attempt shall be made to determine the bottom characteristics on each shoal and bank within the range of visual fixes. On off-lying shoals and banks of 50 fathoms or less beyond the range of visual fixes, such bottom characteristics shall be determined as are practicable in each case. If of exceptional importance one or more survey buoys may be located for use in referencing spot stops for the purpose of obtaining bottom data, especially if survey buoys are being used in the hydrographic control of the area.

When soundings are taken by machine and wire, the character of bottom shall be determined at least at each position, and if the soundings are in comparatively deep water and widely spaced, a determination should be made at each sounding.

Since the use of echo sounding has become more prevalent in hydrographic surveying, the character of the bottom cannot be determined with the ease and frequency it could when handlead and wire soundings were more commonly used. When a resurvey is being made of an area where sufficient determinations of the bottom were made during a prior survey, it will be sufficient to test a small percentage of these to determine whether there have been any changes, and if not, the coverage of the prior survey in this respect may be considered a part of the coverage required for the new survey.

Echo-sounding surveys of harbors, anchorages, shoals, and banks in areas where the hydrography is controlled by visual fixes shall be followed by a second coverage of the area during which spot stops are made to secure the information relative to bottom characteristics. Supplemented by data from prior surveys, the coverage in

such areas must be sufficient to show the character of the bottom throughout the entire area, including a demarcation of the limits where one general type of bottom changes to another. In depths suitable for anchoring, a knowledge of the consistency of the bottom is more useful than the descriptive characteristics or the color of the bottom material.

In offshore areas surveyed by echo sounding, controlled otherwise than by visual fixes, as many well-distributed bottom characteristics shall be determined as practicable without additional cost or additional stops during actual sounding. Bottom characteristics shall be determined whenever the vessel stops for any reason whatsoever within the project area if the information can be obtained during the period of time the vessel is to be stopped. Bottom characteristic determinations shall be made in conjunction with each serial temperature and each vertical cast. They shall be made at each anchorage of the vessel on the working ground and at the position of each survey buoy. Such bottom characteristics shall be recorded in the Sounding Record, accompanied by the position data and by a short statement of the vessel's activities at the time. If a fixed position is impracticable, dead-reckoning data from a known position should be given.

An attempt shall be made to cover the area as uniformly as practicable with bottom characteristic determinations, as outlined above, and the determinations which are made at times other than during sounding shall be indexed on page 2 of volume 1 of the Sounding Records.

During echo sounding, bottom specimens can frequently be obtained from a vessel underway by the use of a power-driven sounding machine and stranded wire where the depths do not exceed 50 fathoms.

To ensure a determination of the bottom characteristic at each stop in an echo-sounding survey, a snapper or other adequate bottom sampler should be used if there is the slightest evidence that the bottom material is such that it may be washed from the sounding lead.

In submarine valleys and canyons and other unusual submarine relief of interest to scientists as well as mariners, a special effort shall be made to determine bottom characteristics more frequently than would be considered necessary in other areas of similar depth.

### *3843. Classification of Bottom Characteristics*

Descriptions of bottom types are of most value to the mariner and the scientist if they follow a standard classification and utilize standard abbreviations. The latter are furnished in part "S" of the Symbols and Abbreviations chart (see fig. 189). Descriptive terms needed, which are not included in the chart, should be written out in full.

A complete description of a bottom characteristic consists of three parts: One or more adjectives descriptive as to size or consistency; one or more adjectives designating color; and one or more nouns naming the class of bottom material, the abbreviations of which are always capitalized. These are to be arranged in the following order: Descriptive adjective, color, noun. (See also **783**.)

### *3844. Types of Bottom Material*

The marine deposits commonly encountered by hydrographers in coastal surveys are sediments composed chiefly of terrigenous material with which may be mixed one or two other constituents. The several constituents may be briefly described as follows:

*a. Terrigenous material.*—These are derived from erosion of the land, and consist of rock fragments and mineral particles from the size of boulders down to colloidal dimensions. Terrigenous material

comprises most of the sediments on the continental shelves and slopes, and also occurs in parts of the ocean deeps adjacent to land.

*b. Organic material.*—Remains of animals and plants, common in many areas near land.

*c. Volcanic material.*—Debris from volcanoes, rare except in volcanic regions.

*d. Chemical material.*—Material deposited chemically or formed on the sea floor by chemical action. Included are phosphatic nodules, manganese nodules, and glauconite. The last is common in many areas near land.

### *3845. Classification of Sediments*

The basis for the classification of sediments is the size of the particles composing them. For a precise typing a mechanical analysis is necessary, but this is ordinarily impracticable in hydrographic surveying.

Sediments may be generally classified into three main groups: (*a*) sands, (*b*) those finer-grained than sand, and (*c*) those coarser than sand.

Sand is generally easily recognized; even the finer-grained sands feel gritty when rubbed with the finger on the palm of the hand, and if scattered when dry, will separate into grains easily visible to the naked eye. When mixed with water in a test tube it sinks rapidly, usually in less than 1 minute, and is to a noticeable degree conductive of water.

Technically there are two grades of sediment finer than sand. These are *silt* and *clay*. Because of the frequent difficulty in distinguishing them without special apparatus, for practical purposes they are often both classified under the general term *mud*. When the grains are finer than 0.05 mm in diameter, they have lost the physical properties of sand. The specimen no longer feels gritty when rubbed in the fingers, and if dropped on a hard, level surface, the grains will not separate, but will congregate into small heaps. Several minutes are required for the particles to sink in water to the bottom of a test tube. Clay is a finer-grained deposit than silt. Sediments composed of clay are stiff in nature and sticky to the touch. *Ooze* is very soft or ooze-like.

Sediments are variously typed according to the size of the particles composing them. There is no exact agreement among scientists as to classification but the following tabulation will serve as a gage for classification of the sands and coarser particles. It is not intended that the dimensions be measured. A careful estimation by eye is satisfactory. Sand grains are easily visible and their relative coarseness can be closely estimated with a little practice.

TABLE 7.—*Sediments classified by size*

| Sediment | Diameter of grains | |
|---|---|---|
| | *In millimeters* | *Approximate equivalent in inches* |
| Ooze | | |
| Clay, Silt } Mud | 0.02– 0.1 | |
| Sand, very fine | 0.1 – 0.2 | |
| Sand, fine | 0.2 – 0.3 | |
| Sand, medium | 0.3 – 0.5 | |
| Sand, coarse | 0.5 – 1.0 | |
| Gravel, fine | 1 – 2 | 1/25 – 1/12 |
| Gravel, medium | 2 – 4 | 1/12 – 1/6 |
| Gravel, coarse | 4 – 6 | 1/6 – 1/4 |
| Pebbles, fine | 6 – 10 | 1/4 – 2/5 |
| Pebbles, medium | 10 – 20 | 2/5 – 4/5 |
| Pebbles, coarse | 20 – 50 | 4/5 – 2 |
| Stones | 50 –250 | 2 –10 |
| Boulders | 250 upwards | 10 upwards |

Sediments generally do not consist of particles of one size; sand is commonly mixed with gravel or shells, and mud with sand. If the deposit consists almost entirely of one constituent, only one noun should be used; but if it consists of two or more constituents, the name of the dominant constituent shall be placed first, followed by the other or others as accessories. Thus, if a deposit of mud contains a considerable proportion of sand, it should be recorded as *M S* (mud, sand); if a mud deposit contains shells, it should be recorded as *M Sh* (mud, shells). If a deposit consists of shells or coral so broken and ground up that the general size of the particles corresponds to that of sand, it should be recorded as *sh S* (shell sand) or *co S* (coral sand); in this case the words shell and coral are descriptive and their abbreviations should begin with lower-case letters.

If a specimen contains *specks* of contrasting color or size, the abbreviation *Sp*, immediately preceded by any descriptive terms, should follow the term designating the type of deposit.

### *3846. Nature of Bottom Materials*

The nature, such as soft, hard, sticky, stiff, or the size, as coarse, fine, etc., of the materials is indicated by an adjective preceding the noun. The abbreviations of the adjectives shall always begin with lower-case letters. The usage of most of the terms is self-evident.

When the consistency of the bottom material is determined by *feeling* only, without an examination, it shall be described by one of the adjectives, such as sticky, hard, or soft, unaccompanied by a noun indicative of the material. Nouns shall be used only when the bottom material has been visually examined. The use of the term *rocky* is to be avoided in this respect; the term *hard* should be used instead in all cases where applicable. The term rocky may be used when it is known that the bottom is bedrock or consists of a material larger than gravel but no specimen can be secured for examination. The term *broken* should be used as a modifying term to describe the condition of shells or coral. (See also **783.**)

### *3847. Colors of Bottom Samples*

The color of the specimen should always be noted while it is wet, as the color of some sediments is different when dry. The terms *dark* and *light* should never be used alone; they are intended for use in qualifying the intensity of a given color, as for example, light gray, dark green. Where the color of the specimen is best described by a combination of two colors, it may be done by hyphenating the two colors, the predominant one being placed last, as yellow-green.

Unfortunately, color perception differs considerably in individuals so that uniformity is difficult to achieve. For best results two or more individuals should examine and agree as to the color of the specimen.

### *3848. Geographic Distribution of Deposits*

Close to shore and on the continental shelf the marine deposits generally consist of sands, gravels, and muds, with which are frequently mixed the remains of animals and plants. These are the sediments which are defined in **3844.** They are usually found in depths of less than 100 fathoms, and within an average distance of 75 miles from land.

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Beyond the above zone to approximately 200 miles from land, the ocean bottom deposits are still considerably influenced by the nature of the adjacent coast, and in these deeper areas, down to about 1,000 fathoms, which we may consider on the continental slope, the deposits consist principally of blue, green, and red muds formed by the deposition of the finest clays which have been carried to the sea by rivers. The shells of marine animals are also found in these deposits. The different colors result from the presence of various minerals. Fine bluish-black or blue muds are most frequent, although green mud also occurs frequently. Red muds are relatively rare.

In oceanic areas remote from land, the deposits consist principally of the remains of organisms living in the ocean, in which are to be found small quantities of wind-carried volcanic debris and very fine terrigenous materials. The principal types are:

*Globigerina Ooze* occurs at an average depth of 2,000 fathoms, most commonly within the range from 1,200 to 2,200 fathoms, although it has been found from 400 to 3,000 fathoms; it is the characteristic deposit in the Atlantic Ocean. It consists principally of the debris of the minute calcareous shells of the Foraminifera, especially the globular form *Globigerina* of characteristic shape. It is dirty-white in color when dried.

*Radiolarian Ooze* is abundant in the Pacific Ocean, occurring at an average depth of 2,900 fathoms, most commonly within the range from 2,000 to 5,000 fathoms. It is not found in the Atlantic Ocean. It is nothing but red clay containing a large number of the minute siliceous skeletons of *Radiolaria*, a group of the Protozoa. It is frequently mixed with the principal constituent of globigerina ooze, but this latter is rarely found in deposits in the greater depths. Its color is red or dark brown; it is less plastic than red clay alone.

*Diatom Ooze* is found at an average depth of 1,500 fathoms, in a range from 600 to 2,000 fathoms. It is found extensively in the Antarctic Ocean and in the North Pacific Ocean. It consists of the siliceous remains of a primitive group of microscopic plants, with which clay and Radiolaria are commonly found. It is white in color.

*Red Clay* is the most characteristic and widely distributed oceanic deposit, occurring in depths greater than 2,225 fathoms and in the greatest depths of the oceans. It is formed almost entirely of insoluble residues, consisting of wind-blown dust, generally of volcanic origin, which by a long process of decomposition form red clay. In the North Atlantic the color is brick-red, owing to the presence of iron oxide. The calcareous and to a large extent the siliceous materials, which characterize the oozes, are gradually dissolved as they sink slowly to the ocean bed and so are rarely present in these depths.

### 385. Descriptive Report and Coast Pilot Notes

It is obvious that satisfactory Descriptive Reports of hydrographic surveys cannot be written from memory after the completion of the survey, nor by a person who was not in charge of the actual field work.

A daily journal shall be kept by each hydrographer in which a complete set of notes is made concurrently with the progress of the survey. The notes should include information about the various items required in Descriptive Reports (see **842**), but in no case should they take the place of remarks and miscellaneous entries properly belonging in the Sounding Record (see **815**).

In some cases extenuating circumstances may justify the omission of a sounding line, a deviation from standard methods, an apparently incomplete development, etc. A complete record should be made of such circumstances by the hydrographer while they are fresh in his mind.

Occasionally, for one reason or another, it is impracticable for the hydrographer to write the actual Descriptive Report, or the hydrographic smooth sheets may have to be plotted under the supervision of some individual who did not have personal knowledge

of the field work. In all such cases the daily journal of the hydrographer making the survey is invaluable.

Such a journal should, of course, be neatly made from rough memoranda accumulated during the day. As the survey progresses, earlier entries should be reviewed from time to time and any which are finally inapplicable should be carefully ruled out or the entries restated as necessary. Each entry should be initialed by the person who made it and each journal accompanying an unplotted or incompletely plotted hydrographic survey or partial survey to be completed by another party should be authenticated by the Chief of Party.

After the complete Descriptive Report has been prepared, journals or notebooks which have served their purpose can be destroyed.

During a hydrographic survey each hydrographer should keep a journal in which notes and memoranda are entered for use in compiling the general coast pilot report at the end of the season (see **159**).

## 39. SPECIAL TYPES OF SURVEYS

### 391. Wire-Drag Surveys

Sounding, in rocky regions, even where the sounding lines are closely spaced, is insufficient in itself to ensure that all existing obstructions, pinnacle rocks, boulders, and ledges have been found and that the least depths over them have been determined.

Before such areas can be considered to be thoroughly surveyed they should be wire dragged. In many cases, owing to the high cost of wire-drag surveys, thorough coverage and development by sounding has to be considered sufficient, at least temporarily. It must be borne in mind, however, that the only positive way to find the highest point of, and the least depth over, a rock or pinnacle whose top cannot be seen, is by means of the wire drag.

For the final examination of such areas, the Coast and Geodetic Survey has developed an apparatus known as the *wire drag*, consisting of a horizontal wire which is towed through the water by a vessel at each end, and which will strike or *hang* on any obstruction rising above the depth at which it is set. The wire is maintained in a horizontal position at any desired depth below the surface by means of weights suspended from floating buoys by cables and by submerged floats attached to the wire at regular intervals. The depth of the wire below the surface can be varied as desired by the upright cables between the weights and the surface buoys, as the cables are wound on reels mounted on the tops of the buoys.

The *wire sweep* is a modification of the wire drag for use in regions where the general depths are considerably deeper than the depth to be verified and where few, if any, obstructions are to be expected. The buoys are much farther apart than in the drag, and no provision is made for varying the depth of the wire while dragging or for preventing the sag of the wire between buoys.

Wire-drag surveys are ordinarily executed by parties especially organized for the duty and the vessels used have often been built for this kind of work. But the survey ships and the larger auxiliary vessels are equipped with a short wire drag, 2,000 to 3,000 feet long, utilizing standard equipment. On the survey ships the buoys are stowed in racks on the upper deck and are kept ready for use at all times; the remainder of the equipment may be stowed in the most convenient place but it must be kept clean, dry, and free from rust. The wire drags for the auxiliary vessels are usually stored on shore until needed.

The construction and operation of the wire drag and sweep are described, and instructions for wire-drag surveys are contained, in Special Publication No. 118.

### 392. Survey in Advance of Control

When, in exceptional cases, it is advantageous to carry on hydrographic or topographic surveys simultaneously with or in advance of the triangulation, the work must be planned with the view of ultimate compliance with the control specifications. In order to save time or to utilize the services of all of the party at the beginning of the season, preliminary locations of the control stations may be determined by sextant cuts or three-point fixes for use on the boat sheet. It is to be understood that the stations will finally be accurately located and these positions used on the smooth sheet. If the preliminary locations are so weak as to cast doubt on the adequacy and coverage of the survey, the work should be replotted in ample time to permit additional field work before the party leaves the field.

Likewise with a topographic survey in advance of the triangulation, the methods used should be planned so that the ultimate result will comply with the control specifications. In an area where the coastline is regular, usual traverse methods may be used on a sheet without projection, to which a projection is added after several of the stations within the area have been accurately located by triangulation. This can be done only where there is reasonable assurance that any discrepancies are the result of accumulated systematic errors. A projection can be applied to such a sheet by one of the methods described in **737**. For topographic surveys of complicated areas, final acceptable results can be obtained only by the subsequent location by triangulation of a comparatively large number of the control points. A new projection must be made on which these common control points are plotted and to these the details from the original sheet must be transferred, area by area, and adjusted.

### 393. Isolated Harbor Survey

It is sometimes desirable to survey an anchorage or a harbor in an unknown region in advance of the regular survey of the area and prior to the establishment of the permanent control.

A method of establishing local control by planetable triangulation is described on pages 51 and 52 of Special Publication No. 144, Topographic Manual. This may also be done by sextant triangulation. The stations thus located may be used to control a survey of the harbor and its approaches to any extent desired. The data so obtained if based on local astronomic observations can be used for the construction of a preliminary harbor chart. If it is expected that permanent control will be extended into the region within a reasonable time, some of the stations used should be permanently marked for subsequent connection with the general control scheme.

If time does not permit a complete survey of an isolated harbor, a partial reconnaissance survey can be made by less accurate methods. A few signals erected on salient points or a few buoys anchored and located by cuts may serve as the control. The survey should include a measured base, and in lieu of one measured by tape, a stadia or taut-wire distance will suffice. A meridian should be established, and in lieu of more accurate methods, a sun azimuth may be measured by sextant.

The shoreline and topographic details may be sketched with reference to the located stations from the sounding boat during the hydrography. The part of the area

to be recommended as an anchorage should be sounded thoroughly, the soundings in other parts being frequent enough to give a general idea of the depths.

The methods described under this heading should be used only as a last resort and when lack of time prevents the use of more accurate methods.

## 394. Reconnaissance Survey

A reconnaissance survey is a hasty preliminary survey of a region made to provide some advance information regarding the area which may be useful pending the execution of more complete surveys. Such a survey is made in a rapid manner, frequently covers an extensive area on a comparatively small scale, and is almost invariably uncontrolled by triangulation. The resulting survey is frequently no more than a sketch of the area, and if soundings are made these are sparse and give only the most general idea of the depths of water in the area.

The resulting map or chart from such a survey is merely a sketch map and, if published, the representation should not be shown with exactness in a manner to mislead the user. The legend of such a map or chart should indicate clearly its quality.

### *3941. Running Survey*

Practically all surveys executed by the Coast and Geodetic Survey are parts of an accurately controlled systematic survey of an area. However, in an unknown region far from established control, a running or exploratory survey may be resorted to which will serve at least to determine the general form of the coast and the character of the area, and serve as a reconnaissance for the extension of control into the area and the thorough survey to follow. The results are far from accurate but they do give a rough and superficial examination of an extensive area when time does not permit a more detailed survey. The use of a large scale is unwarranted—a scale of 1:100,000 or smaller will usually suffice.

As the accuracy of the survey depends almost exclusively on the dead reckoning, the errors of the logs and compasses must be accurately determined in advance and the corrections must be carefully applied when the results are plotted. If a taut-wire apparatus is available it may be used to obtain an accuracy in distance impracticable by the use of logs. The accuracy of the courses may sometimes be improved by running the successive courses on ranges selected from time to time, as for example, the tangent of an islet in range with a distant peak.

In a running survey the ship steams along at a safe distance from the coast, its position being fixed by dead reckoning and astronomic observations. Soundings are taken at the same time. As the ship proceeds along its course, angles and bearings are measured to all identifiable points on the coastline and to conspicuous objects inland, the clock times of the various observations being recorded to correlate the data with the dead reckoning. All off-lying islands, islets, and rocks should be located and their shapes comparatively well delineated. All prominent points along the coast should likewise be located and, where practicable, occasional locations should be made in the bays and indentations between the points, although often the detail between the prominent points will have to be sketched.

The best results are obtained by the use of a moderate and constant speed with as few alterations in course as practicable and without stopping the vessel to make any of the observations.

A minimum of three or more directions should be observed to each object as a check both on the accuracy of the work and the identification of the object. It must be expected that these directions will usually not intersect at a point, but the triangle of error shoud be small enough to ensure that the observations have been taken to the same point and that there will be little difficulty in selecting an acceptable position. Rapid sketches, made at the different positions, of the details to which the observations were made will be of material assistance in correcting and adding to the data when plotted.

If the depths permit, a still more accurate and complete running survey may be based on a series of buoys anchored by the ship during its dead-reckoning line, the distances and azimuths between them being measured by taut wire and sun azimuths from the ship. After this line of buoys is in place and their positions are available, a hydrographic survey of the area and a survey of the shoreline to any extent may be carried out.

Each running survey should start and end with a fixed position. Such positions can rarely be related to the basic control; generally they are based on astronomic observations. When the astronomic observations at the ends of the line and during the dead reckoning have been computed and positions have been determined, all of the data should be replotted and readjusted to these positions.

The amount of detail to be obtained during a running survey will depend on the amount of time available. Additional detail, especially of the inshore area, may be obtained by employing a launch in conjunction with the ship to sketch in the smaller detail, the position of the launch being located from time to time with reference to the ship at a prearranged signal between the two. The launch itself may run a dead-reckoning course which is related to the ship's dead reckoning, taking soundings at the same time. Better results are probably obtained by dispensing with the sounding and letting the launch proceed at will to various strategic points where it stops to measure angles and sketch in detail, each position of the launch being referred to the ship's dead reckoning.

All of the observations should be recorded and all bearings and angles should be plotted at the time they are observed in order to detect any errors in identification or measurement while the detail to which the observations were made is still in view.

In making a running survey a number of observers and recorders are essential and the various phases of the work must be divided between them so that each has a definite duty to perform and not more than he can do efficiently. One observer usually takes astronomic observations and supervises the dead reckoning; two or more may be employed in identifying shore objects and measuring angles and bearings to them; another may be employed in identifying various hills and summits and measuring horizontal and vertical angles to them. One person experienced in that kind of work should make sketches of the coast which may be related later to the points which have been located.

Regardless of the method used in a running survey or the accuracy attained there will be discrepancies in the results and the hydrographer has the problem of effecting a satisfactory compromise, which can best be done only by one who has had long experience in this type of survey.

# CHAPTER 4. EQUIPMENT AND INSTRUMENTS

## 41. SURVEY SHIPS AND AUXILIARY VESSELS

The modern survey ships of the Coast and Geodetic Survey are steam or motor vessels approximately 200 feet in length, with facilities to accommodate a complement of 10 to 20 officers and 60 to 70 crew. This personnel is sufficient to operate three or four launch hydrographic parties, two or three topographic or triangulation parties, and be engaged in ship hydrography simultaneously. The storage space is sufficient to carry a 6 months' supply of materials and equipment for survey operations, and provisions consisting of frozen vegetables and meat, canned goods, and other food staples. The fuel and water capacity enables the ship to remain for periods of 3 to 4 weeks on a working ground distant from port.

The survey ships of the Coast and Geodetic Survey are listed in table 8 with dimensions and particulars tabulated with appropriate notes.

Each ship is designed and equipped to enable the survey party aboard to operate as a complete and independent unit for combined operations and in offshore and remote areas. On the working ground the ship is used to survey the greater part of the offshore hydrography, in addition to serving as living accommodations for topographic, triangulation, and launch hydrographic subparties which work independently from the ship during the daytime. Equipment is carried for the establishment of one or more shore parties, which are often supplied at regular intervals. Many other operations, through which data for the compilation of nautical charts are obtained, are performed by the personnel on board the vessel.

Auxiliary vessels of the Coast and Geodetic Survey are designed to operate independently or in conjunction with a survey ship. The larger vessels have sufficient fuel and hold capacities to remain on the working ground for periods of at least 2 weeks and, in general, are small models of the larger survey ships. Some of the smaller auxiliary vessels are equipped for wire-drag surveys in addition to the more usual hydrographic surveys. Auxiliary vessels are generally used for surveying in protected waters and, if operated independently, not far from a shore base or headquarters.

The dimensions and particulars of the auxiliary vessels of the Coast and Geodetic Survey, in 1942, are contained in table 9. They range from 52 to 98 feet in length and generally contain living accommodations for sufficient personnel to operate them for hydrographic surveys and an additional supplemental unit engaged in topography, triangulation, or small-boat hydrography.

### 411. General Description of a Survey Ship

A well-designed survey ship has suitable quarters for officers and crew, ample storage space for supplies, and efficient apparatus for carrying, lowering, and hoisting survey launches and small boats. A well-lighted and fully equipped drafting room and a large well-equipped pilothouse are essential in hydrographic surveying, and there should be suitable spaces for the installation of sounding and position-finding apparatus. The propelling machinery and deck machinery are subjected to hard usage and should be of sturdy construction.

TABLE 8.—*Survey ships of the Coast and Geodetic Survey in 1942*

| Name | Displacement loaded | Length between perpendiculars | Beam | Mean draft | Propulsion | Total I. H. P. | Maximum speed | Cruising radius | Fuel capacity | Complement | | Built |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Officers | Crew | |
| | *tons* | *feet* | *feet* | *feet* | | | *knots* | *miles* | | | | |
| DISCOVERER [1] (ex AUK) | 1, 180 | 160 | 35. 6 | 12. 6 | Triple expansion, reciprocating engines. | 1, 400 | 13 | 5, 500 | 82,000 gallons fuel oil. | 12 | 57 | 1918 |
| EXPLORER | 1, 850 | 198. 7 | 38. 0 | 15. 0 | Steam turbine | 2, 000 | 15 | 8, 000 | 88,650 gallons fuel oil. | 23 | 68 | 1940 |
| FATHOMER [2] | 550 | 144 | 25. 0 | 9. 6 | Compound reciprocating engines. | 400 | 10 | 2, 000 | 90 tons coal | 7 | 41 | 1904 |
| GUIDE [1] (ex FLAMINGO) | 1, 180 | 160 | 35. 6 | 12. 6 | Triple expansion, reciprocating engines. | 1, 400 | 13 | 5, 500 | 82, 000 gallons fuel oil. | 12 | 57 | 1918 |
| HYDROGRAPHER [3] | 1, 000 | 148 | 31. 5 | 12. 0 | Diesel electric | 700 | 11 | 6, 000 | 32,000 gallons Diesel oil. | 10 | 51 | 1931 |
| LYDONIA | 585 | 181 | 26. 0 | 11. 4 | Four cylinder triplex fore and aft. | 600 | 11 | 1, 800 | 106 tons coal | 8 | 49 | 1912 |
| OCEANOGRAPHER [3] (ex CORSAIR). | 1, 400 | 270 | 33. 3 | 16. 0 | Two triple expansion vert. inverted with two low pressures. | 4, 500 | 16 | 4, 500 | 85,000 gallons fuel oil. | 9 | 59 | 1899 |
| PATHFINDER [3] | 1, 900 | 209. 3 | 39. 0 | 15. 0 | Steam turbine | 2, 000 | 15 | 9, 000 | 110,000 gallons fuel oil. | 19 | 68 | 1942 |
| PIONEER [1] (ex OSPREY) | 1, 180 | 160 | 35. 6 | 12. 6 | Triple expansion, reciprocating engines. | 1, 400 | 13 | 5, 500 | 82,000 gallons fuel oil. | 12 | 57 | 1918 |
| RESEARCH [4] (ex PATHFINDER). | 875 | 168 | 33. 6 | 13. 0 | Triple expansion, reciprocating engines. | 846 | 12 | 3, 000 | 240 tons coal | 9 | 71 | 1899 |
| SURVEYOR | 1, 150 | 170 | 34. 3 | 12. 0 | Triple expansion, reciprocating engines. | 1, 060 | 12 | 4, 800 | 73,000 gallons fuel oil. | 11 | 59 | 1917 |

[1] The DISCOVERER, GUIDE, and PIONEER transferred in 1941 to U. S. Navy for duration of World War II.
[2] Owned by the Commonwealth of the Philippine Islands and assigned to the Coast and Geodetic Survey.
[3] The HYDROGRAPHER, OCEANOGRAPHER, and PATHFINDER transferred in 1942 to U. S. Navy for duration of World War II.
[4] Loaned to the Commonwealth of the Philippine Islands and assigned to the Coast and Geodetic Survey.

TABLE 9.—*Auxiliary vessels of the Coast and Geodetic Survey in 1942.*

| Name | Displacement loaded | Length between perpendiculars | Beam | Mean draft | Propulsion | Total I. H. P. | Maximum speed | Cruising radius | Fuel capacity | Complement: Officers | Complement: Crew | Built |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *tons* | *feet* | *feet* | *feet* | | | *knots* | *miles* | | | | |
| COWIE [1] | 128 G | 98 | 18.5 | 6.8 | Two Diesel engines | 300 | 13.8 | 1,800 | 2,300 gallons Diesel oil. | 5 | 14 | 1927 |
| E. LESTER JONES | 150 | 82 | 21.0 | 8.0 | Two Diesel engines | 300 | 10 | 3,000 | 4,460 gallons Diesel oil. | 3 | 12 | 1940 |
| ELSIE III | 24 | 52 | 11.6 | 4.0 | Gasoline engine | 45 | 8 | 400 | 310 gallons gasoline | 2 | 5 | 1912 |
| FARIS [2] | 44 | 75 | 13.7 | 4.6 | Two gasoline engines | 400 | 15 | 300 | 1,000 gallons gasoline | 3 | 8 | 1924 |
| GILBERT | 95 | 66.7 | 16.5 | 7.0 | Diesel engine | 130 | 8.3 | 4,000 | 3,133 gallons Diesel oil. | 3 | 12 | 1930 |
| HILGARD [3] | 45 | 65 | 15 | 4.5 | Two Diesel engines | 170 | 10.5 | 675 | 510 gallons Diesel oil | 2 | 6 | 1942 |
| MARINDIN [3] | 36 | 60 | 14.8 | 4.6 | Two gasoline engines | 80 | 10 | 300 | 300 gallons gasoline | | 6 | 1919 |
| MITCHELL [3] | 36 | 60 | 14.8 | 4.6 | Two gasoline engines | 80 | 10 | 300 | 300 gallons gasoline | | 6 | 1919 |
| OGDEN [3] | 36 | 60 | 14.8 | 4.6 | Two gasoline engines | 80 | 10 | 300 | 300 gallons gasoline | | 6 | 1919 |
| PATTON | 150 | 82 | 21.0 | 8.0 | Two Diesel engines | 300 | 10 | 3,000 | 4,460 gallons Diesel oil. | 3 | 12 | 1941 |
| RODGERS [3] | 36 | 60 | 14.8 | 4.6 | Two gasoline engines | 80 | 10 | 300 | 300 gallons gasoline | | 6 | 1919 |
| WAINWRIGHT [3] | 45 | 65 | 15 | 4.5 | Two Diesel engines | 170 | 10.5 | 675 | 510 gallons Diesel oil | 2 | 6 | 1942 |
| WESTDAHL | 90 | 67.7 | 15.5 | 7.5 | Diesel engine | 140 | 7.5 | 4,350 | 4,060 gallons Diesel oil. | 3 | 12 | 1929 |
| WILDCAT | 45 | 65.6 | 15.3 | 6.0 | Gasoline engine | 85 | 8 | 650 | 1,200 gallons gasoline | 2 | 10 | 1915 |

[1] Former names are PERKINS, R–DREAM, and RHEA III.
[2] Former U. S. Coast Guard patrol boat.
[3] Built for wire-drag surveys.

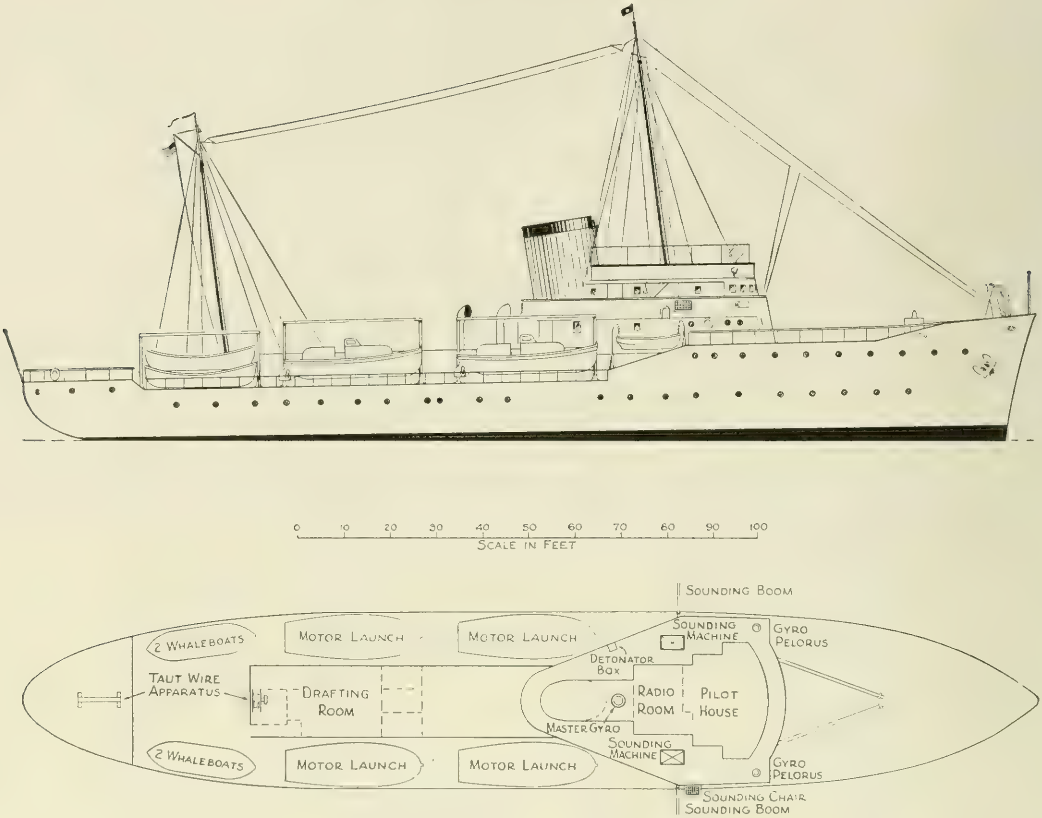


FIGURE 68.—General plan of a survey ship.

### *4111. The Bridge*

The bridge is the most important part of a ship used for hydrographic surveys and, since so many observations are taken from it, it is necessary that there be as clear a view from it as practicable all around the horizon. The pilothouse is the control station where all survey operations are conducted or from which they are supervised, and it is obviously important that it be suitable and spacious.

In all hydrographic surveys, except those controlled by R.A.R., the pilothouse or bridge is where the positions are plotted on the boat sheet and the soundings and control are officially recorded, in addition to the usual navigation which is performed. In hydrography controlled by visual fixes, all sextant angles are observed from the bridge or the flying bridge. The echo-sounding instrument is usually inside the pilothouse, the wire sounding machine is on the bridge just outside, and the handlead sounding platform is on the wing of the bridge. In hydrography controlled by R.A.R., many of the details are performed in the radio room and drafting room.

During hydrographic surveys various personnel are in the pilothouse and on the bridge, all of whom are busily occupied with operations which must be performed quickly and accurately. In order that these operations may be efficiently performed with a minimum of confusion, it is essential that the pilothouse and bridge be especially designed for hydrographic surveying and that they be fully equipped and conveniently arranged with the most modern navigation and survey equipment and instruments.

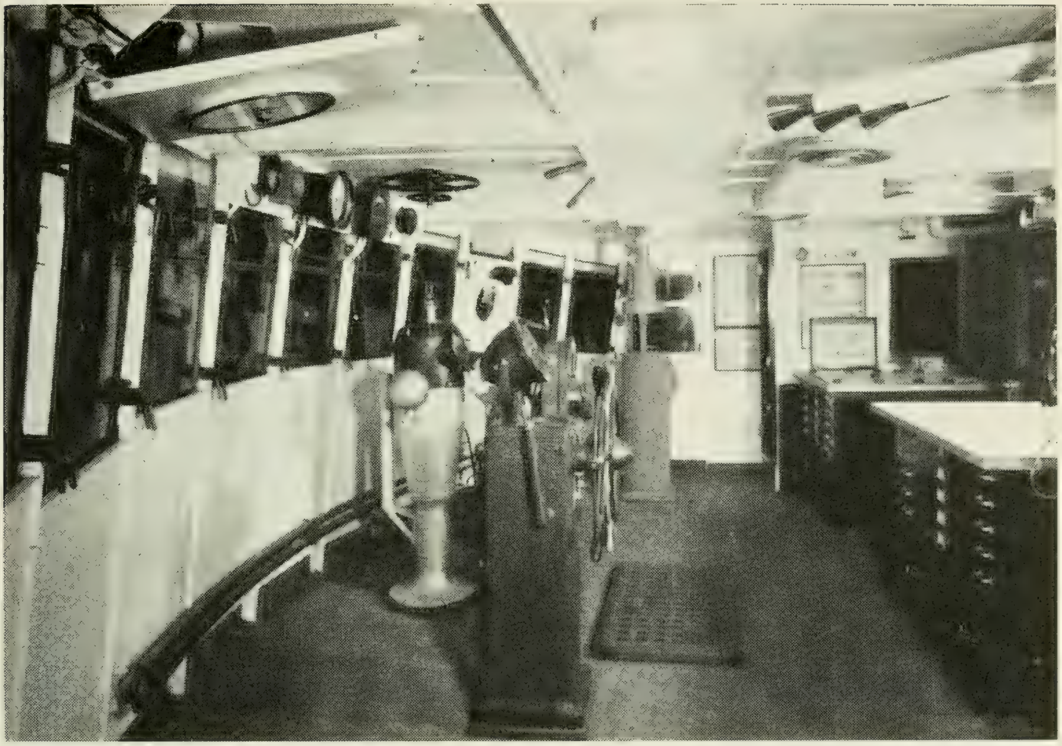

Figure 69.—Pilothouse of a survey ship.

A well-designed pilothouse has several doors to provide convenient access to all parts of the bridge and to the radio room if it is adjacent, and an inside passageway to the main part of the ship. It contains chart cases and racks conveniently located for charts, boat sheets, and tracings. The chart cases have table tops on them on which charts and boat sheets may be spread for use in navigating and plotting. A desk is provided for the use of the recorder during hydrographic surveying and the navigator at other times. The desk is specially constructed to house the chronometers under a glass top, and contains drawers for books, tables, and nautical publications. Numerous lockers or cabinets are provided in which the sextants, binoculars, protractors, flags, etc., are stowed when not in use. To provide a working area for navigation and R.A.R. hydrography at night, the pilothouse is arranged so that the after portion, including the echo-sounding instruments and one chart case, may be blocked off by an opaque curtain.

In addition to the customary navigation and control equipment, the bridge of a survey ship contains the following special or specially used survey instruments and equipment:

(*a*) Two echo-sounding instruments for alternate use in ship hydrography; at least one of these should be a Dorsey Fathometer No. 3.

(*b*) A gyrocompass and pilot for steering sounding lines in R.A.R. and astronomically controlled hydrography.

(*c*) Two electric sounding machines, one on each side of the bridge, for vertical casts, water samples, and bottom specimens.

(*d*) A gyro repeater on each wing of the bridge for use in taking bearings.

(*e*) Electric push-button bell for use in marking fixes or signaling other hydrographic operations.

(*f*) A loud-speaker system for two-way communication between the pilothouse and various parts of the ship; this is especially useful during taut-wire measurements, R.A.R., and other survey operations, and when hoisting and lowering survey launches and small boats.

(*g*) A rangefinder and a gyro repeater on the flying bridge.

Other equipment located on the bridge or in the pilothouse, which is only indirectly connected with hydrographic operations but deserves mention, includes a manually and electrically operated whistle and siren, radio direction finder (unless located in the radio room), clear-view screen, propeller-shaft revolution indicator, rudder-angle indicator, indicator for electric logs, telephone system, light-control switchboard, fire-control system with automatic smoke indicators, automatic alarm howlers, and control for operating the $CO_2$ fire-control system and for closing the watertight doors.

### *4112. The Radio Room*

The radio room of a well-designed survey ship is located directly aft of the pilothouse, from which it can be entered by an interior door, and with which it is connected by telephone and speaking tubes. In addition to the usual ship radio communications, many operations connected with R.A.R. are conducted in the radio room. A chronograph installed here is used in R.A.R.

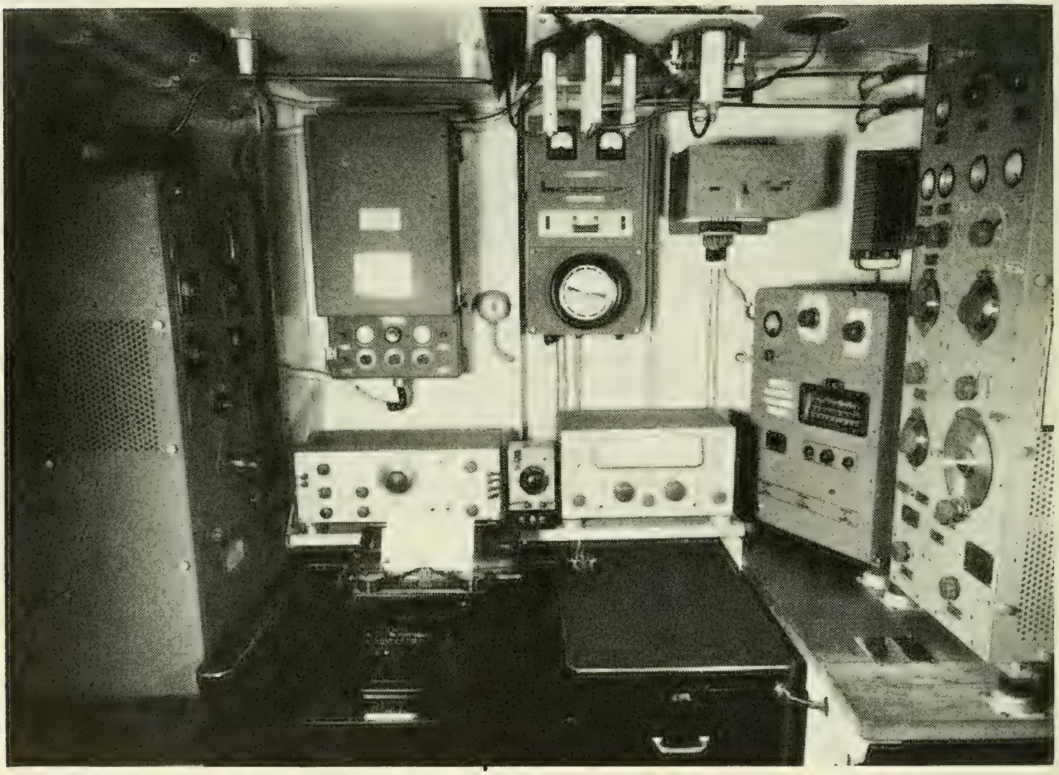

FIGURE 70.—Radio room of a survey ship.

The radio room should be of sufficient size to accommodate without congestion the necessary radio equipment for survey use and ordinary communications. The communications equipment for code should consist of two transmitters and two receivers. One of the transmitters should be for intermediate-frequency communications, rated at 1,000 watts, and crystal-controlled to operate on 375, 400, 425, 454, and 500 kilocycles. The power to operate this transmitter should come from the ship's power

supply, but for emergency purposes it should be capable of being operated at a reduced power of 50 watts from a 12-volt heavy-duty storage battery. The intermediate-frequency receiver should be battery operated, or a combination receiver operated from either a battery or alternating current.

The second code transmitter should be a crystal-controlled high-frequency transmitter with a 150-watt rating. Two frequency-controlling crystals, one of 4135 kc and another of 4160 kc, should be provided in the transmitter. It should be capable of operating on the harmonics of both crystals, up to and including the third harmonic. Power to operate this transmitter should be from the ship's power supply. The high-frequency receiver should have an approximate frequency range from 0.5 to 30 megacycles. It may be either a-c or d-c operated, although the former is usually preferred.

In addition to the regular equipment, there should be an automatic S O S alarm and a ship-to-shore telephone. The radio room, or one adjacent to it, should have sufficient space for workbenches and stowage of tools, spare parts, and other equipment.

The radio technicians, in addition to their routine radio duties, repair and keep in good order the echo-sounding instruments, radio direction finder, chronograph, etc.; build, repair, and service sono-radio buoys and R.A.R. shore stations; build and repair radio sets and attend to their installation in launches and camps; and design and develop, for use in survey operations, new instrumental equipment which involves the use of radio or electricity, and improve existing equipment.

### *4113. Ship Drafting Room*

The importance of the drafting room on a survey ship is second only to the pilothouse and bridge, and because of the considerable amount and kind of work which is done in it, it is essential that it be ample in size and well lighted.

The drafting room should be large enough to contain several drafting tables, a desk or two, a file case, and a rack for boat and smooth sheets. The drafting tables generally consist of table tops mounted on a base in which there are numerous large and medium-sized drawers in which to stow flat the smooth sheets, topographic sheets, drafting paper, charts, and maps; and for record books and small drafting instruments and equipment. The tops of the drafting tables are specially constructed of laminated selected white pine, 1½ inches thick, stiffened on the underside, with kerfs to prevent warping.

Where space permits, one large drafting table should be about 8 feet long for use in constructing large boat and smooth sheets and circle sheets (see **3741***c*).

There should be bookshelves for the various manuals, tables, and reference books; and a locker conveniently accessible in which confidential data may be locked.

The importance of the illumination cannot be overemphasized. There should be as many windows to admit natural light as practicable and a system of indirect lighting or fluorescent lamps to eliminate shadows and to give near-daylight conditions at night. The latter is particularly important as a large amount of night work is necessary in connection with many of the hydrographic and survey operations. Improper lighting strains the eyes, especially at night after they have been used all day. With the illuminating equipment now available an improperly lighted drafting room is inexcusable, and the use of lights of low wattage and the operation of the ship's generator at a low voltage are considered false economy. They lead to expensive errors and inaccurate work.

FIGURE 71. Drafting room of a survey ship.

### *4114. The Ship's Office*

An independent room for a ship's office is a valuable asset to a survey ship. The reports, accounts, and correspondence are important functions of any large party, and the work in connection with them can be more efficiently conducted in a room especially reserved for this purpose. Having to perform this type of work in makeshift quarters, such as the drafting room, wardroom, or staterooms, tends toward a perfunctory performance and increases the possibility of misplaced or lost papers and correspondence.

The ship's office should be located nearby and conveniently accessible to the Commanding Officer's quarters. It should be large enough to contain desks or tables for the accounting officer, the chief writer, and one or two assistants; a safe; and numerous filing cabinets, shelves, and pigeonholes for an orderly and systematic conducting of routine and current duties. All furniture and fixtures should preferably be of metal construction.

## 412. SHIP "EXPLORER"

The *Explorer* (see fig. 1) is probably the most modern survey ship afloat in 1941. The survey equipment is the newest and best available, and the construction is as completely fireproof as possible in a survey vessel.

The principal specifications of the *Explorer* are as follows:

| | |
|---|---|
| Length overall | 220 feet, 8 inches. |
| Length between perpendiculars | 198 feet, 8 inches. |
| Breadth, molded | 38 feet. |
| Depth, molded, to upper deck | 23 feet. |
| Draft, molded, mean load | 15 feet. |
| Displacement, loaded | 1,850 tons. |
| Shaft horsepower | 2,000. |
| Speed at 130 r. p. m. | 15 knots. |
| Cruising radius | 8,000 miles. |
| Water | 175 tons. |
| Fuel oil | 320 tons. |
| Diesel oil | 13 tons. |
| Gasoline | 5 tons. |

### *4121. General Description*

The ship is of all-steel construction, with a raked stem and cruiser stern, complete main and upper decks, a lower deck forward and abaft the machinery space, and a long superstructure deck. Double-bottom tanks, extending from the forepeak aft to frame 75, are subdivided for fuel oil and water. The forward tanks extend up to the lower deck, and the double-bottom tanks below the machinery spaces extend up the sides to the lower-deck level for bilge protection. Between frames 75 and 85 is a dry tank under the lower deck, aft of which is the afterpeak.

The hull is subdivided by eight watertight bulkheads so arranged that the vessel is a two-compartment ship. Bulkhead plating and stiffeners are welded throughout. There are only three openings in the bulkheads below the upper-deck level and these may be closed by watertight doors of the sliding type, electrically controlled from the pilothouse, and in case of failure they may be closed from the upper deck by emergency hand-operated controls.

The shell seams are riveted and the butts flush-welded. The deck plating is riveted to the beams; the seams and butts are welded. The decks have no sheer and only the upper and superstructure decks are cambered. Calked wooden decking is laid over the weather decks, fastened with galvanized iron deck bolts, cut to length, and welded to the deck. Through bolts are not used. The shell plating and decks are supported by a system of transverse framing, spaced 27 inches apart, and by transverse web frames and longitudinal girders.

The propelling machinery consists of a steam turbine operating a single propeller through a double-reduction gear in a single case. Steam is provided by two watertube boilers, with a working pressure of 350 pounds per square inch with 200° Fahrenheit superheat at the superheater outlet. The engines and boilers are in separate compartments amidships.

The electric plant consists of: two turbine-driven main generators, each of 50-kw capacity, 120-volt direct current, two-wire, compound-wound, arranged for parallel operation; a 25-kw d-c motor generator, directly connected to a 40-hp a-c three-phase, 220/440-volt motor installed for the purpose of converting shore alternating current to 120-volt direct current for ship use during lay-up periods; a 10-kw d-c Diesel generator for emergency use; and two 5-kva 60-cycle turbo-generators used in connection with the operation of echo-sounding apparatus, synchronized clocks, and other survey equipment.

The evaporating and distilling plant has a rated capacity of 2,000 gallons of fresh water for 24 hours.

Accommodations are provided for 23 officers and 68 men. The living quarters are adequate, properly lighted, heated, drained, ventilated, equipped, located, and arranged, all in accordance with existing rules of the United States Bureau of Marine Inspection and Navigation for new construction. The decks in the accommodation spaces are covered throughout with an approved latex-type deck covering or ceramic tile. The furniture in general is of steel construction built to Navy Department specifications.

A well-appointed hospital space suitably fitted with berths, toilet facilities, medicine lockers, X-ray machine, etc., is located at the main deck level.

A mechanical ventilating-and-blower system provides 10 changes of air per hour in accommodation spaces and 15 changes per hour in toilet, galley, and hospital spaces. The ventilation of living quarters is provided by four supply and four exhaust fans and the machinery spaces are ventilated by two supply and one exhaust fan. Designated spaces are heated by tempered outside air.

The galley and pantries are completely outfitted with steam tables, cupboards, cabinets, etc., whose exposed metal parts are generally of Monel metal, as are also the sinks and bulkheads back of the galley range and around the steam pressure cooker. The galley and pantry equipment includes an oil-burning galley range, an electric range, refrigerators and water coolers, electric mixer, electric vegetable peeler, etc.

The refrigeration system is of the automatic direct-expansion type, using Freon as a refrigerant. The entire interior of the storage spaces is lined with Monel metal, which is sanitary, easily cleaned, and lasting. Glass wool in block and blanket form is used to insulate the refrigeration spaces.

A combined carbon-dioxide fire-extinguishing and smoke-detecting system with smoke detectors at the $CO_2$ outlets, provides fire protection for machinery spaces and in dangerous fuel compartments. In addition, there are 42 thermostatic detectors, connected to the fire-alarm system, provided in the various storerooms, lockers, and hold spaces on the upper, main, and lower decks.

The water system is served by two duplex steam, fire, and wrecking pumps. Portable fire extinguishers, fire axes, breathing apparatus, flame safety lamps, etc., are provided at strategic places. Magazine flooding is provided.

The ship is equipped with several types of interior communication. In addition to the usual voice tubes, call bells, and telegraphs, there is a loud-speaker system designed to provide for general announcements from the pilothouse to various parts of the ship, to provide two-way conversation between the pilothouse and any of the talk-back speaker stations, and to provide for the amplification of an alarm siren over all of the loud-speaker system. A sound-powered, selective ringing, marine-type telephone system is installed to provide interior communication throughout the ship, with an acoustic telephone booth installed in the engine room.

### 4122. *Equipment of the "Explorer"*

The bridge and pilothouse of the ship *Explorer* are equipped with navigation and survey instruments of the latest type and design for accuracy and precision. The Sperry gyrocompass system comprises a master compass, a steering repeater, two bearing repeaters, a radio-direction repeater, a course recorder, and a gyro pilot. The magnetic compasses, compensating binnacles, and a special 1-meter rangefinder to fit the gyro repeater on the flying bridge, are standard United States Navy equipment.

Three echo-sounding instruments—a Dorsey Fathometer No. 3, a 312 Fathometer, and a Veslekari depth recorder—are installed in the pilothouse. Two electric sounding machines, one an LL-type using stranded wire and the other a deep-sea type using piano wire, are installed, one on each side of the bridge deck, and are used for vertical casts and to obtain bottom samples and water specimens. Among other electric survey and navigation equipment in or controlled from the pilothouse are two submerged Meridian logs, a taffrail log, a whistle, and a synchronized clock system.

The installed radio equipment includes two radio transmitters for communication by code, an intermediate-frequency set and a short wave set; an automatic S O S alarm; a ship-to-shore radio telephone; and a radio direction finder. In addition there are two types of radiotelephones for use by detached parties; one is semiportable for use by launch parties and shore camps, and the other is portable for itinerant survey parties for communication with each other. The latter is intended for shoulder or saddle packing through rough terrain and in mountain climbing. The entire assembly of transmitter, receiver, power supply, and dry battery power source is contained in one carrying case. The transmitter is crystal-controlled and is designed so that it can be set up or dismantled in 3 minutes by personnel without technical radio knowledge.

Survey equipment includes a taut-wire apparatus for measuring water traverses with great accuracy, and sono-radio buoys for use in R.A.R. controlled surveys.

The launches and small boats carried by the *Explorer* are as follows:

Four Diesel-powered 30-foot launches.
Two gasoline-powered 24-foot whaleboats.
Two nonmagnetic 24-foot whaleboats.
Two 16-foot dinghies.
Several Cape Cod skiffs and fisherman-type dories.

The drafting room is equipped with four drafting tables, two typewriter desks, a file case, and a survey sheet rack. Each drafting table consists of a wooden table top permanently secured to the top of a metal case containing numerous drawers and compartments of various dimensions to hold charts, Whatman sheets, aluminum-mounted topographic sheets, small drafting instruments and

supplies, stationery, etc. In addition to the regular electric illumination of the room, a special fluorescent lamp of the daylight type is installed above each drafting table to provide near shadow-elimination. Two drafting tables, similar to those in the drafting room, are installed in the pilothouse.

An adequate supply of theodolites, alidades, portable tide gages, sextants, protractors, binoculars, etc., of the latest types and design is included in the survey equipment.

## 413. Motor Vessel "E. Lester Jones"

One of the most modern auxiliary vessels of the Coast and Geodetic Survey is the twin-screw Diesel-powered wooden motor vessel *E. Lester Jones*. The dimensions are an over-all length of 88 feet, a breadth of 21 feet, and a normal draft of 8 feet. The vessel is designed for an independent survey unit, equipped with all the essential items found in the larger survey ships, except that no power launch is carried. The complement consists of 3 officers and 12 men.

FIGURE 72.—Motor vessel *E. Lester Jones*. The *E. Lester Jones* is 88 feet long, 21 feet beam, and 8 feet draft. Her complement is 3 officers and 12 men. She operates as an independent unit.

### 4131. General Description

The hull is stoutly built, with keel, double flitch-frames, planking, ceiling, and decks of Douglas fir. All lumber has been pressure-treated with "Wolman" salts for protection against dry rot and decay. All hull fastenings are of Monel metal and others are bronze. There are four watertight steel bulkheads.

The hull design is full with good freeboard, a straight stem, well-flared bow, and elliptical overhanging stern. There is a large deckhouse and considerable open deck space. Some of the characteristics of a halibut schooner are embodied in this able, trim craft.

The propelling machinery consists of two Diesel engines, each rated at 150 hp at 500 r.p.m. The vessel has a maximum speed of 10 knots, a cruising radius of 3,000 miles, and a fuel capacity of

4,460 gallons of Diesel oil. The engines are designed for fresh water cooling with heat exchangers. Located in the stack are surge tanks for the propelling Diesels and silencers for the main engine exhausts and the auxiliaries.

Below deck are, from bow to stern, a forepeak and chain locker, a forecastle, engine room, wardroom, and lazaret. In the forecastle are 12 built-in berths for the crew. The engine room is 15½ feet in length. In addition to the Diesel engines, it contains two 28-hp Diesel-powered auxiliary units, each consisting of an electric generator, an air compressor, a fuel-oil transfer pump, an all-purpose water pump, and a heat exchanger complete with fresh and raw water pumps. Both units are cross-connected to alternate their duties. The wardroom contains accommodations for three officers, various lockers, the Commanding Officer's desk, and a table.

On the upper deck, the pilothouse is in the forward end of the deckhouse. The crew's messroom, extending the full width of the deckhouse, is located amidships, and aft of it is a complete galley, equipped with an oil-burning range. In the after end of the deckhouse are the cold storage compartment, a refrigerating room, and mess stores lockers. The companionway to the wardroom below is located amidships.

There are two Diesel oil tanks and two fresh water tanks forward and two of each aft. The total fresh water capacity is 2,500 gallons.

The fire-control system includes two automatic remote-control $CO_2$ extinguishing systems, one in the engine room and the other in the lazaret and paint locker.

### *4132. Equipment of the "E. Lester Jones"*

The navigation equipment installed in the pilothouse of the *E. Lester Jones* includes a photo-electric pilot for automatic steering (similar to a gyro pilot but actuated by a magnetic compass) and a radio direction finder, in addition to the standard equipment carried by vessels of this size. Visibility from the pilothouse in rain or heavy weather is aided by an electrically operated clear-view screen. Also installed in the pilothouse is a complete sending-and-receiving radio set.

The sounding equipment consists of a Dorsey Fathometer No. 3 for echo sounding and an LL-type sounding machine with stranded wire for vertical casts. The former is located in the pilothouse and the latter on the port deck.

In addition to the sounding equipment, the vessel is equipped with the usual survey instruments, including theodolites, alidades, portable tide gages, sextants, etc., of the latest types and design.

Four small boats provided with outboard motors are carried; two 16-foot dinghies for lifeboats and two dories for landing parties ashore. The dinghies are stowed in chocks on the upper deck and the dories are carried on the afterdeck, being lowered and hoisted by a small boat boom.

## 42. SURVEY LAUNCHES AND SMALL BOATS

### 421. General Description of Survey Launches

Most of the launches used in hydrographic surveying are open or partly decked 30-foot boats, propelled by internal combustion engines, with a maximum speed of approximately 8 knots, but which can be run continuously, without choking, at the slow speeds of 2 or 3 knots during the development of shoal areas. The launches are used for sounding inshore and for the development of shoals or shoal indications where a ship or auxiliary vessel cannot operate safely or economically. They are also used to transport shore survey parties to and from their work. Since the launches operate from a ship, camp, or shore headquarters, living accommodations and storage space for supplies are not required.

Portable depth recorders are used for echo sounding from most survey launches. They reproduce a profile of the bottom in depths up to 160 fathoms and permit running the launch at full speed. This method of sounding has replaced the old handlead and wire methods to a large extent, and results in more progress and a more accurate survey. Many of the launches are also equipped for radiotelephone communication with each other, the mother ship, or shore parties.

When handlead and machine sounding methods are used extensively, a reversible propeller is desirable to eliminate much of the wear and tear on the clutch and reverse gear from the frequent stops required for vertical casts. The fact that the engine operates at a constant speed whether going forward, astern, or at a stop, reduces carbon fouling to a minimum and hence makes the motor more dependable. This feature is not essential if the launch is equipped with a portable depth recorder, in which case the conventional propeller, which is more efficient, should be installed.

A survey launch should be seaworthy, strongly constructed, and should have as much clear space in the cockpit as practicable. Most survey launches are hoisted and carried on board the large survey ships, but sometimes, through necessity, they are towed from place to place, especially where they are to be operated in conjunction with one of the auxiliary vessels, which cannot hoist them.

There are two principal types of survey launches used by the Coast and Geodetic Survey. One is the United States Navy motor sailer with an open cockpit covered with a canvas canopy. The other has a similar hull but is partly decked, with two canopy-covered cockpits separated by a small deck at gunwale height for navigation and hydrographic survey operations. The standard length of both types is 30 feet, with a 3-foot draft. They are equipped with either gasoline or Diesel engines. Diesel engines are being installed exclusively in all new launches to eliminate the hazard of explosion and fire that is ever present when gasoline is used. The launches are constructed with hoisting pads and rings and where they are a part of the ship's equipment, they are stowed in chocks on the ship between periods of use. The launches have a lifeboat capacity of 24 to 30 men and a fuel capacity of 50 to 100 gallons.

The open cockpit type of launch is preferable for transporting signal-building parties, camp supplies, lumber, and bulky supplies. The partly decked or enclosed launch with the engine in a separate cockpit is more suitable for hydrographic surveying since the various operations can be more efficiently conducted where they are separated from the engine compartment and motor noises.

Shallow draft launches are used for hydrographic surveying in extensive shallow water areas. These afford adequate room for the personnel and necessary equipment of a hydrographic survey unit. The launches are 26 to 28 feet in length and their draft is not more than 10 or 15 inches when loaded.

### *4211. Launch of Ship "Explorer"*

One of the new launches of the *Explorer* is illustrated in figure 73.

It has a length of 30 feet, width of 8½ feet, draft of 3 feet, is of sturdy wooden construction, and is designed especially for inshore hydrography along exposed coasts. A 35-hp Navy-type Diesel engine propels the launch at about 7½ knots at 1,400 r.p.m.

The launch is decked over except for the two cockpits. Aft of a forward deck 6 feet long is the forward cockpit, which is 9½ feet long. There is a 3½-foot deck amidships, aft of which is the after cockpit 6¾ feet in length, extending to the afterdeck which is 4¼ feet long. A narrow 8-inch deck extends around the sides of the cockpits, which are surrounded by a coaming or washboard extending 6 inches above the deck. Both cockpits are fitted with canvas canopies, covered-wagon type. The afterdeck has a tubular rail around its edge. At the forward end of the midship deck section there is a bulkhead surmounted by a Lucite flexible glass windshield. There is a centerline opening through the bulkhead for entry to the forward cockpit. The steering wheel and engine controls are located on the port side of the bulkhead between the midship deck and the forward cockpit, and the coxswain conns the launch from this point.

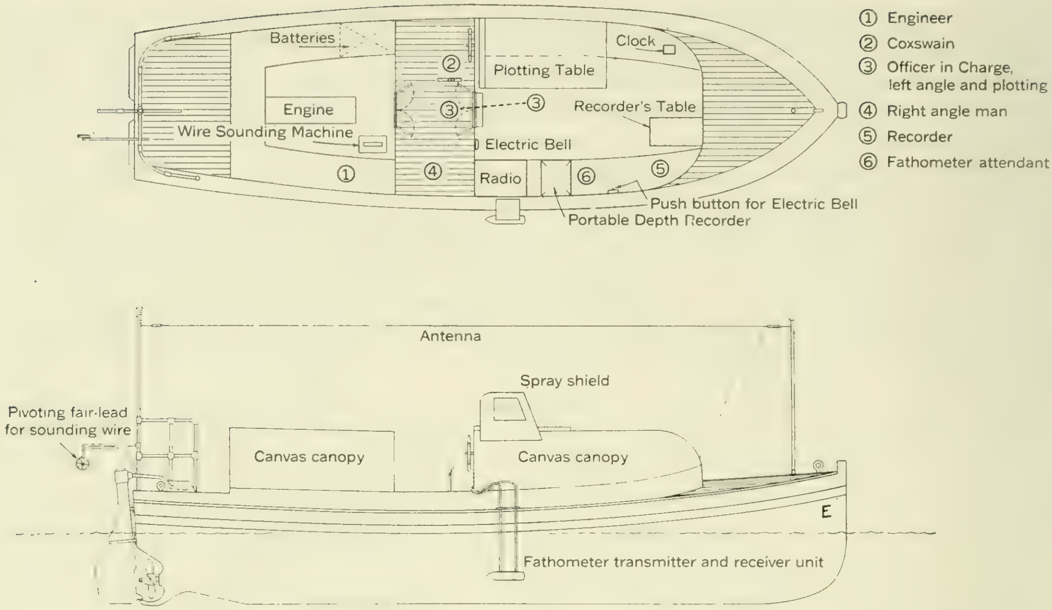


FIGURE 73.—General plan of a survey launch.

## 422. LAUNCH EQUIPMENT

A modern survey launch is equipped with a portable depth recorder, a sending-and-receiving radiophone, antenna poles, a wire sounding machine, running lights, fire extinguishers, first-aid kit, emergency rations, fresh water breakers, anchors, etc. Other instruments, such as sextants, protractors, compass, clocks, and binoculars, are kept on board the ship when not in use.

The portable depth recorder is housed in a metal cabinet 21 inches in length by 17 inches in width by 10 inches in height, weighing in all 103 pounds. It is operated by electricity supplied by two 6-volt 200-ampere hour storage batteries connected in series. Sound impulses are sent out and the returning echoes are received through units housed in a *fish* submerged over the side of the launch just forward of the mid-ship deck. The fish is usually about 2 feet below the surface of the water. The received echo registers the depth on a facsimile paper with printed scale, producing a continuous profile of the bottom in depths to 160 fathoms while the launch is running at full or reduced speed. Complete details of design and operation are given in **523**.

The radiophone operates from the same batteries as the portable depth recorder. With it the launch party can communicate with the survey ship at distances of at least 50 miles and with other launch parties or shore camps at distances up to 20 miles.

For vertical casts and bottom samples, soundings are obtained by handlead or wire. The wire sounding machine is power-operated by a jackshaft from the launch engine. The wire is lead aft over a fair-lead attached to the rail. This arrangement is satisfactory when wire soundings are obtained only intermittently and when the launch is completely stopped before the lead is released. However, if soundings are taken regularly with wire, a special stanchion is necessary which will ensure keeping the wire away from the propeller; or the machine may be installed so that the wire may be led over the side of the launch by the use of a portable boom with fair-lead on the end. (See **4633.**)

## 423. LEASED LAUNCHES

To supplement available launches or to execute a small independent survey, it is sometimes necessary to lease one or more privately owned craft. The procedure to be followed in leasing launches is subject to change and officers are cautioned to familiarize themselves with the most recent instructions on the subject before proceeding. The correct procedure, in effect March 1942, is contained in paragraphs 676 to 678 of the Regulations of the Coast and Geodetic Survey, supplemented by **4231** and **4232** of this Manual. Paragraph 675 of the Regulations has been canceled.

### *4231. Procedure in Leasing Launches*

Before leasing a launch, estimates must be submitted in the usual manner and, after their approval, invitations should be issued for competitive bids on Standard Form 33, if the period of time is less than a month; or on Form 508, if the time is longer but the amount involved is less than $5,000. If the total cost of the rent of one or more launches may equal or exceed $5,000 for the period specified, competition shall be obtained through advertising in one or more newspapers as prescribed in paragraph 627 of the Regulations. Time must be allowed for departmental approval for amounts of $5,000 or more (see par. 640 of the Regulations) so as not to delay the beginning of field operations.

Specifications for the lease of launches should be as broad as practicable to obtain the widest competition, at the same time furnishing a basis for the rejection of bids on unsatisfactory craft. The requirements under such of the following headings as are applicable should be stated definitely in the specifications and the bidder should be required to furnish sufficient information with his bid to show clearly whether his launch meets the requirements:

Type.
Length limits.
Beam limits or fineness ratio.
Speed requirements.
Draft.
Type of engine and control.
Accommodations.
Equipment.
Statement of locality and requirements of work to be performed.
Period of lease.
Delivery point.
Government to furnish fuel and supplies.

The specifications should also contain the following item regarding the employment of an engineer:

"*Engineer:* The owner (lessor) shall designate and employ an engineer who will furnish his own subsistence. The engineer's salary will be paid by the owner, and hence must be included in the bid price for the hire of the launch. The engineer will have full responsibility for the operation and care of the engine and will be the owner's representative."

The number of launches required must be stated in the invitation, otherwise only one launch can be accepted.

Any test or trial necessary to determine compliance with the specifications should be made before recommending acceptance.

Whenever time permits, a copy of the invitation and specifications should be forwarded to the Washington Office and the advertisement made sufficiently in advance to permit forwarding the bids, abstract of bids, and recommendation to the Office by mail for approval of award, thus avoiding the necessity of using the telegraph.

The lowest bid on a launch complying with the specifications must be accepted. In case the lowest bid is not recommended for acceptance, the recommendation should set forth the items of the specifications with which such low bid does not comply.

Before a bid is accepted, the results of the bidding, including any particulars which are important, should be forwarded to the Washington Office—by wire, if time is important—and authority should be requested to accept the low bid meeting the specifications. After authority has been received, the bid should be accepted and, if the period of time is more than 1 month, a formal contract should be signed with the owner of the craft, using Form 509, Lease of Launch. This lease with accompanying bids and papers should be forwarded to the Washington Office promptly after the contract has been signed.

### *4232. Inspection Report of Leased Launch*

A complete inspection report, dated and signed, shall be forwarded to the Washington Office promptly at the beginning of every lease of a vessel or launch, and likewise on the termination of the lease. The survey of the hull, machinery, and equipment shall be made by a board of three officers, one of whom is an engineer officer. If three wardroom officers are not available to make the survey, competent petty officers in the crew may act as members of the board to assist the senior member.

### *4233. Desirable Type of Leased Launch*

The most satisfactory type of launch usually available for lease for use in surveying is the fishing or working type to be found in the locality where the survey is to be made. Such launches are generally seaworthy, adaptable to hydrographic surveys, and can be obtained at reasonable rates. They are invariably built to meet the conditions encountered in the particular locality. One-man pilothouse control is preferable to two-man control and the latter should never be used if the former is available. The smaller type of fishing or working boat is usually constructed with a small cabin forward and a large open cockpit over which is a removable awning. Yachts and pleasure craft are generally unsatisfactory.

Many such launches are powered by regular marine Diesel or gasoline engines, but some are powered by automobile motors converted to marine use. The motor conversion consists of the installation of a more powerful water pump, a special manifold, and a reverse gear. Some installations use the automobile transmission for reverse gear, but the marine clutch with reverse gear is sturdier and better. Another type of power plant encountered in some launches is the old heavy-duty slow-moving one-, two-, or three-cylinder type. It is reliable but slow, and is usually direct-connected to the propeller. A clutch and reverse are necessary in any launch to be used in hydrographic surveys.

Speed is not essential in a launch to be used for handlead or wire sounding; reliable motor performance at low speed is more important. On the contrary, if a portable graphic recorder is to be used for sounding, or if the launch is to be used to transport a topographic or signal-building party to and from the working ground, speed is of prime importance.

## 424. Small Boats

Various types of small boats are used for sounding close to shore, surf, breakers, or other dangers; for running to and from the working ground; for transportation of topographic, triangulation, and other working parties operating from a ship; and for sounding in shallow water when shallow-draft launches are not available. All of these boats can be propelled by oars; most of them are designed so that outboard motors can be attached, although inboard engines are installed in some of them.

### *4241. Whaleboat*

Whaleboats are very serviceable double-ended open boats of full beam and considerable sheer, principally used as lifeboats. They are generally 24 feet in length, with a beam of 6 feet 10 inches, and they draw not to exceed 2½ feet when fully loaded; they weigh varying amounts, averaging about 2,000 pounds; they have a lifeboat capacity of 23 men. They are equipped with air tanks forward and aft. Some whaleboats are power-driven by inboard gasoline or Diesel engines.

Whaleboats are quite seaworthy, even when heavily loaded, and are very useful for the transportation of personnel and equipment in open waters, where the sea is usually rough and turbulent, and for landing through surf. They are splendid boats for the use of topographic parties on an open coast, for transporting supplies and equipment to camps, for carrying lumber and other supplies for signal-building parties, and for towing other motorless boats laden with supplies. They are not particularly suitable for use in sounding.

### *4242. Dory*

A dory is a small flat-bottomed boat with sharp sheer; it is almost double-ended, having a narrow V-stern. It is a typical New England craft, used by all Bank fishermen. A 20-foot dory has a beam of 5 feet 10 inches and draws about 1½ feet when fully loaded; this is the preferred size for use in surveying; it will accommodate a party of three or four men with equipment. Smaller dories, 16 feet in length, have been used but they are too small for most survey parties.

A moderately loaded dory is more stable than one lightly loaded, its one disadvantage being that it is somewhat unsteady when light. Properly managed this boat is most seaworthy, but a layman must use it with caution. It is a good boat for use where landings have to be made on an open coast in a moderate swell. A special well is usually constructed at the stern for the installation of an outboard motor, otherwise the bow and stern are practically alike. This construction makes the dory a good surfboat when either bow or stern is headed into the sea, and landings can be made on the beach by heading straight in through the surf with little danger of swamping, or can be made by turning around and backing in. Dories can be used independently or in conjunction with a launch.

### *4243. Skiff*

A skiff is a light motorless boat with a flat bottom, square stern, and fair freeboard. It is light and easily handled but is not especially seaworthy. The flat bottom and wide stern make the boat steadier than a dory but it does not have as much freeboard or riding ability.

A skiff is useful in more or less protected waters and is ordinarily used in conjunction with a launch, being towed from place to place and then used for landings and transportation along the beach. An 18- or 20-foot skiff is most satisfactory for the use of survey parties; one less than 16 feet long is practically useless. Outboard motors can be attached and used on skiffs if desired.

A small skiff carried on a trailer towed by a truck can be used advantageously by field inspection parties engaged on air photographic surveys, where a boat is occasionally needed in protected waters. This eliminates having to rent small boats and the time spent in obtaining them.

### *4244. Gondola-Skiff*

The gondola-skiff is an oversize skiff, developed by the Chesapeake Bay seine fishermen. It is about 25 feet long, with a 7½-foot beam overall, and has a 5½-foot square transom, which is cut away for the installation of an outboard motor. The bottom is flat and thwartship planked, with a keel and keelson each consisting of a heavy plank laid flat. The bow is decked over for 5 feet aft of the stem. There is a 7-inch deck extending along each side of the boat with a small coaming or washboard on the inboard edge. This boat has proved very suitable in areas like Chesapeake Bay, Albemarle

Sound, and the Indian River district for the use of shore-based survey parties. The boats are cheap to construct, have a shallow draft, and will carry a fair-sized party or load.

### *4245. Dory-Skiff*

A dory-skiff is 16 to 20 feet in length and combines some of the characteristics of a dory and skiff. It is flat bottomed with straight side planking of fair sheer, a dory bow, and a skiff stern. This combination gives the boat the forward riding ability of a dory, but eliminates the unsteadiness; it provides a larger capacity and a convenient arrangement for an outboard motor attachment.

The disadvantages are that it is heavy and difficult to handle in a wind, because the bow, being higher out of the water than the stern, catches the full effect of the wind and tends to turn the boat broadside. This makes the boat susceptible to swamping, especially when landing on or taking off from the beach in a moderate wind and swell. A dory-skiff is not satisfactory for use in exposed waters where strong winds and heavy swells are frequent.

### *4246. Knuckle-Skiff*

A knuckle-skiff combines some of the characteristics of the dory and the skiff, and is usually 16 to 18 feet in length. It is flat bottomed and has a dory bow and skiff stern. The lower side planking is at a decided angle and the upper side planking is more nearly vertical. There is a pronounced knuckle at the junction of the upper and lower side planks.

This boat has a moderate sheer, is fairly light in weight, and cheap to construct. It has a good capacity and handles well in protected waters, such as in Southeast Alaska or Puget Sound, but it is not recommended for independent use in exposed waters because of its low freeboard and lack of reserve buoyancy. The boat can be backed in to a rocky shore and held there long enough for men to jump ashore or aboard, because the wide stern provides a good footing.

An outboard motor may be used to advantage with this type of boat.

### *4247. Dinghy*

A dinghy is a round-bottomed boat with a bar-type keel and slight sheer, and is usually 12 to 16 feet in length. This type of boat is usually clinker-built, though sometimes it is carvel-built or smooth sided. A dinghy costs considerably more than a skiff of comparable size.

A dinghy is light in weight, well balanced, and easily handled, and is useful for the transportation of small parties in protected waters. It is not satisfactory for use along rocky coasts because its frail hull is easily punctured and the type of construction makes repairs exceedingly difficult. Because of this, its use should be confined to protected areas with muddy or sandy shores. Outboard motors can be attached.

Dinghies are most useful in connection with auxiliary vessels since they are easy to lower, hoist, and stow, and because the working grounds are usually located in protected areas. On large survey ships they are rarely used by survey parties, but they are useful and required as emergency boats, for use in handling lines, and in case of a man overboard, etc.

A dinghy is not intended for use in making beach landings and should not be so used. The round bottom with bar keel tends to make it overturn as soon as the keel touches bottom, particularly when there is any surf.

### *4248. Catamaran*

A catamaran is a two-hulled craft, the hulls being joined by cross beams. Two boats of the same type and dimensions are generally used, either dinghies, skiffs, or dory-skiffs. An outboard motor is usually attached to the stern of one of the boats, but may be attached alongside, or to the deck between the two boats. Sometimes a whaleboat is used alongside a smaller boat to which the outboard motor is attached.

The main advantage of a catamaran is as a substitute for a shallow-draft launch for hydrographic surveying in protected waters when such a launch is not available. The two boats, when properly secured together, give the craft a stability which permits the freedom of movement required by the personnel of a hydrographic party.

The shallow draft enables the craft to go close inshore and to operate freely over extensive shallow areas. Survey parties operating from auxiliary vessels have constructed catamarans and used them successfully when no other means were available to accommodate a launch hydrographic party.

FIGURE 74.—Handlead sounding from a catamaran.

### *4249. Sea Sled*

A sea sled, occasionally useful in surveying, is a light craft of about the same length as a dinghy but with considerably more beam. Its particular characteristics are its shallow draft and concave-shaped bottom, which is tunneled fore and aft along the centerline. The craft attains high speed when propelled by an outboard motor, as the tunnel produces a sort of air pocket and a planing effect, which reduces water friction and enables the sea sled to skim along the surface of the water.

This type of boat is built as a sporting craft, but it can be used to advantage by topographic, triangulation, and signal-building units in *protected* waters for fast transportation to and from the working ground, where parties are based ashore.

## 43. EQUIPMENT AND INSTRUMENTS

A survey vessel must be specially equipped and carry instruments on board, in addition to those ordinarily required for navigation, with which to perform any survey duty likely to be assigned. As the type of project assigned will vary due to the nature and broad scope of hydrographic surveying, much equipment and many instruments must either be carried on board the vessel ready for immediate use, or be available at the Washington Office for use when needed. A sufficient stock of instruments must also be available for the use of shore, launch, or detached parties that may be put in the field.

The Chief of Party must be certain that the necessary equipment and instruments are available prior to the beginning of an assignment. This is particularly important when a vessel is assigned a project in a locality such as Alaska or the Hawaiian Islands, at a considerable distance from Washington, D. C.

Although survey vessels normally are adequately equipped and supplied with all instruments necessary for routine work, a vigilant check must be kept on their condition, utility, and adequacy. Instruments are continually being redesigned, improved, and provided with new attachments, and entirely new instruments are frequently designed. Officers who are continually using survey instruments should be alert to the possibility of improvement and are encouraged to submit recommendations for the redesign of existing instruments and the construction of new ones.

In general, the standard nontransferable navigation and survey instruments installed in place on board vessels or launches are classed as equipment. Most of such equipment is located in the pilothouse or in the immediate vicinity thereto. Vessels constructed especially for this Bureau will be completely outfitted at the time of commissioning; others which may be purchased or received by transfer will probably require the installation of considerable equipment, especially the special equipment used in hydrographic surveying.

In general, portable instruments are classed as instruments; they are not considered an integral part of the vessel but are necessary auxiliaries; they are transferable. A vessel's allowance of instruments varies with the size of the vessel and the project assigned. Instruments shall be kept clean, in adjustment, and in good order at all times. They shall be stowed away in designated places when not in use. They shall be handled carefully at all times, and some of them, like chronometers, require special attention. In survey operations, the Bureau numbers of all instruments used shall be entered daily in the record volume for each particular class of work.

### 431. Care of Equipment and Instruments

The Regulations of the Coast and Geodetic Survey assign to the navigating officer the responsibility for the proper care and maintenance of the navigation equipment and instruments. The responsibility for the proper care and maintenance of the survey equipment and instruments should similarly be delegated to one of the officers. He should make certain that instruments of all types needed are available and in good condition. He should supervise the proper cleaning and drying of all instruments

used in the field and the return of these instruments to the place provided for their stowage. He should make periodic examinations of all instruments on board, provide for their maintenance, make necessary repairs, and keep an accurate inventory. At the end of each season, worn out, damaged, and surplus instruments should be returned to the Washington Office. An officer in charge of any phase of detached operations shall be responsible for the care of his instruments. Before having them stowed away he must be sure that they are cleaned, dried, oiled, and packed in their original boxes.

### *4311. Periodic Tests*

Periodic tests shall be made of various equipment and instruments to check their accuracy, determine their errors, and make corrections if possible. Some are tested during lay-up and overhaul periods while others should be tested at the beginning of and during field operations. The latter is particularly applicable to the magnetic compass as explained in **4415**. Tests required in connection with other equipment are included with the descriptions of the equipment.

### *4312. Care of Equipment*

The safety of the vessel and its occupants often depends directly on the accuracy and reliability of the navigation equipment and the speed and ease with which it can be used.

The equipment located inside the pilothouse and other parts of the vessel shall be kept free from dust, dirt, tarnish, rust, and salt deposits at all times. It should be lubricated according to the instructions for the equipment and inspected and overhauled periodically by experts if the instructions so specify. Equipment kept in boxes or cases when not in use, such as the azimuth circle, shall be thoroughly cleaned and dried before being stowed away, all moisture and salt deposits being first removed.

Equipment installed where it is exposed to the elements shall be kept clean and in perfect condition at all times. Instruments that are not protected by fitted metal covers shall be provided with canvas covers. Exposed equipment shall be kept covered when not in use, except when underway when it may be needed at any moment. All equipment shall be handled carefully to avoid excessive wear and possible damage. Navigation equipment that requires illumination at night shall be inspected at sunset to ensure that all lights are in proper working order; any deficiency shall be corrected at once. Such inspection may be omitted during extended periods in repair yards and alongside docks.

All survey equipment should be cleaned periodically. Surfaces that are apt to become frozen or stuck when stowed for any period of time, should be moistened slightly with oil or tallow after cleaning and before reassembling.

Sounding wire, even when galvanized, is subject to rust. The wire on the sounding-machine reel, when not in use, should be dried, oiled, and well wrapped with oil-soaked cloths, to provide protection from the weather. When sounding, a brush dipped in cup grease should occasionally be held against the wire on the reel as it is being reeled in. (See **4658**.)

When not in use, the sounding machine should be protected from the weather by a canvas cover. The outrigger and sheaves should always be well oiled and should frequently be tested to ensure that the sheaves are turning freely.

Leadlines not in use should be coiled and stowed. All markings should be examined and necessary repairs made at once.

### *4313. Care of Instruments*

Instruments are precision mechanisms, delicately balanced and accurately marked. One bearing or pivot allowed to deteriorate or freeze destroys the accuracy of any observation. For this reason proper and unremitting care is absolutely essential. Every individual using an instrument must realize that the accuracy required in surveying cannot be secured without this care.

The arc of a sextant or protractor may be cleaned by wiping lightly with a chamois skin or soft rag dipped in a weak solution of ammonia. It must never be polished with sandpaper, emery cloth, a rubber eraser, or any other type of abrasive, as the use of such materials will scratch metal and eventually deface the graduations. Alcohol, gasoline, or kerosene should never be used to clean arcs of instruments, as their use will remove the filler from the graduations.

Alcohol, gasoline, and kerosene leave an object extremely dry after evaporation. When they have to be used to remove an excess of oil or grease in the bearings or between bearing surfaces of any instrument, the instrument must not be stowed away until these surfaces have been given a light coating of oil after all the cleaner has evaporated.

All instruments should be carefully dried after exposure to water or dampness, oiled where necessary, and any oil cups refilled. Special attention should be given to lenses and sextant mirrors to ensure that they are thoroughly dried.

Lenses and mirrors may be dusted with a camel's hair brush, or cleaned by gentle rubbing with soft tissue paper or lintproof cloth, after being slightly moistened with the breath. A lens should be examined occasionally to see that it is tight in its cell.

Taffrail logs and current meters are similar in that both have rotating parts constantly exposed to salt water. After use, both should be thoroughly dried, well oiled, given enough turns by hand so that the new oil will have a chance to lubricate all moving parts, and then all oil chambers should be refilled.

### *4314. Repairs to Equipment and Instruments*

So far as possible all equipment shall be maintained in the best working condition by the personnel aboard the vessel. Repairs are to be performed only by experienced and competent technicians. Extensive repairs to heavy equipment, particularly machine work, should be let on contract with firms specializing in the particular type of work. Complicated equipment like the gyrocompass, except for minor details, shall be repaired only by experts representing the manufacturer.

During lay-up or repair periods between assignments, the equipment shall be overhauled and put in the best possible condition in order to reduce repairs and maintenance in the field to a minimum.

Expenditures for repairs to survey instruments shall not be incurred in the field, except where local costs are less than shipping charges to the Washington Office, or in emergencies. Many minor repairs can be made by officers themselves. In emergencies, when the time required to send an instrument to the Washington Office for repairs, or to requisition a replacement, would delay field operations, instruments may be repaired locally. In such a case the voucher for payment must be accompanied by a detailed justification of the action.

A description of the damage to each instrument returned to the Washington Office for repairs must be attached to the instrument. Replacement instruments, if they are needed, should be requisitioned at the same time damaged instruments are forwarded.

### 432. Instrument Requisitions

All items of equipment and instruments are obtained from the Washington Office by requisition of the Chief of Party, using Form 12, Requisition for Instruments and General Property. A requisition for instruments, stating the date when needed at destination, must be submitted to the Washington Office sufficiently in advance to allow adequate time for packing, boxing, and shipping. If the need for any item is urgent, requisition may be made by telegraph or radio, followed by Form 12 forwarded by mail in the usual manner. Such requisitions must be kept at a minimum.

Immediately on receipt of a shipment of instruments, the Chief of Party should have the items checked with those shown on the invoice from the Washington Office, usually mailed on the day of shipment. The number stamped on each instrument should be checked carefully with that on the invoice, so that any discrepancy may be corrected. Each instrument should be closely examined to ensure that there has been no damage in transit and that each is in good working order. Any discrepancy between the invoice and the items received, or any damage, must be reported to the Washington Office at once.

### 433. Accountability for Instruments

The Chief of Party is directly accountable for every item of equipment and each instrument charged to his account. Form 14, Inventory of Instruments and General Property, shall be prepared and submitted in accordance with instructions printed on the back of the form. Each item of property shall be listed on a separate line in alphabetical and numerical order, together with all transactions involved. A smooth copy of this inventory shall be submitted annually, as of December 31, for comparison with the records of the Washington Office.

In the Office, the property accounts of the Commanding Officer of a vessel are filed under the vessel's name, but all others are filed under the name of the Chief of Party. Accordingly, when Commanding Officers are relieved, the transfer of equipment and instruments shall be shown on the regular inventory, Form 14. The inventory shall be brought up to the date of the transfer in all particulars and a receipt, showing that the property as per inventory of vessel was transferred, will be sufficient. When for any reason it is impracticable to bring the inventory up to date, the receipt should be for all items appearing on the Inventory of Instruments and General Property submitted by (*Name of Commanding Officer relieved and vessel*) on December 31 (*year*), amended by all changes to date. A smooth copy of the inventory need not be sent to the Office at this time. When a Chief of Party of an independent field party is relieved, itemized receipts for all equipment and instruments shall be submitted on Form 573, Letter of Transmittal and Receipt for Transfer of Instruments or General Property, as for property transferred between field parties.

When equipment or instruments are transferred from one vessel or field party to another, Form 573 shall be prepared and submitted in accordance with instructions printed on the back of the form. When a field party is disbanded, all instruments shall be returned to the Washington Office or transferred to another vessel or party, the transfer being accounted for on Form 573.

All survey equipment and instruments shall be reported on the ship's inventory, except equipment expended in place which does not bear either Coast and Geodetic Survey or manufacturer's numbers. Replacement parts are expended in place when they are installed.

#### *4331. Expenditure of Instruments*

When equipment or instruments are lost or extensively damaged, the facts shall be reported promptly to the Washington Office. When instruments have become unserviceable through use or age, authority to expend them should be requested from the Washington Office. No inventoriable equipment or instruments may be expended without authority and such authority will not be granted without a complete report of the facts and circumstances. Copies of such letters should be attached to and submitted with the instrument inventory.

### 434. Shipments of Instruments

Instruments that are returned to the Washington Office must be reported on Form 573, Letter of Transmittal and Receipt for Transfer of Instruments or General Property. Instructions on the back of the form must be followed. Shipment must be by the most economic method. A list of the instruments packed in each case shipped must be included in the packing case.

Each instrument to be shipped must be firmly secured in its box, but in such a manner that delicate parts will not be injured by wedging or pressure. Cushions of paper, or other packing material, should be placed not only between the individual instrument boxes but between these and the packing case. Since the packing case may be inverted in transit, the contents must be secured so that nothing in it can come loose. Packing cases containing instruments of various weights should be packed with special care.

Shredded paper, when obtainable, should be used for packing instruments. Chopped-up paper, crushed paper, and cotton make good substitutes. The use of sawdust or excelsior for this purpose is prohibited. An extremely fine dust from these seems to penetrate even hermetically sealed joints. They absorb oil readily and, by contact, may dry the oil from a bearing with probable impairment. They also retain moisture which may damage the contents.

Special precautions must be used in preparing some instruments for shipment. For example, the parts of a standard tide gage which easily become loose, or which might swing about, should be lashed. To prevent the pencil screw from moving endways, one end should be secured to the capstan locknut of the counterpoise drum and the other end to the capstan bearing pin of the pencil screw. The pencil arm should be tied to the hour-tripping rod, which in turn should be lashed to the upper tie rod of the gage. The receiving roller is then lashed to the lower tie rod.

A standard tide gage must also be removed from its packing case with special caution. It must not be grasped by the hour-tripping rod, pencil screw, or other delicate parts during removal, as they might be damaged.

The heavy float and the top and bottom sections of the pipe, usually packed with the portable gage, must be secured firmly to prevent damage to other parts of the gage.

The glass face of any instrument, such as a clock, compass, or pelorus must be protected by a paper cushion. In the case of a compass or pelorus, the instrument should be dismounted from its gimbals, the bottom of its case then padded with soft

material (paper or cloth), and the instrument placed face down in its case. It should then be wedged by additional padding placed between it and the sides of the case.

## 44. NAVIGATION AND POSITION-LOCATION EQUIPMENT

In this section are described the more important navigation and position-location equipment of survey ships and auxiliary vessels, and their use in hydrographic surveying. Ship compasses and compass auxiliaries, the radio direction finder, ship logs, and the taut-wire apparatus are included, but not R.A.R. equipment, which is described in chapter 6.

### 441. MAGNETIC COMPASS

All survey ships and most of the auxiliary vessels of the Coast and Geodetic Survey are equipped with at least two magnetic compasses, the standard and the steering compass; and several of the larger ships have gyrocompasses (see **442**) in addition.

There are two main types of magnetic compasses, the dry compass and the liquid compass. The Coast and Geodetic Survey uses the United States Navy type of liquid compass on practically all of its vessels, launches, and small boats.

Complete and detailed descriptions of the magnetic compass may be found in Special Publication No. 96, Instructions for the Compensation of the Magnetic Compass; and in the American Practical Navigator (Bowditch). Consequently only a brief reference will be made here to the fundamental principles.

#### *4411. Ship Compass*

The liquid magnetic compass is a magnet, or several magnets, attached to a compass card suspended in a liquid with a low freezing point, usually ethyl alcohol. The card rests on a pivot almost without friction, and the entire assembly is enclosed in a nonmagnetic metal bowl. An expansion chamber is provided to compensate for the expansion and contraction of the liquid caused by changes in temperature. On the inner edge of the bowl is a line called the lubber's line, marking the centerline of the ship. The bowl is mounted in gimbals so that it cannot turn in azimuth but will remain nearly horizontal regardless of the motion of the vessel, and to reduce, to a large extent, any dynamic effects due to pitching and rolling of the vessel. The liquid in the bowl serves the double purpose of damping the oscillations of the card and reducing the weight on the pivot. The standard diameter of the compass card used in a ship compass is 7½ inches. All compass cards are graduated in degrees, reading clockwise through 360°.

A ship compass is usually installed in a compensating binnacle of nonmagnetic metal, located on the centerline of the vessel.

Movable magnets and soft iron are provided to counteract the effect of the ship's magnetic field. By means of these the deviation of the compass can be reduced to 1° or 2°. The soft-iron spheres, known as quadrantal spheres, are placed athwartship, one on each side of the bowl and at about the same elevation. Small cylindrical magnets are located in fore-and-aft and athwartship trays beneath the bowl. A Flinders bar is usually located directly forward of the bowl with its axis parallel to the vertical axis of the binnacle. The positions of the magnets are adjustable to provide greater or less effect as needed. (See **4414**.)

For illumination, the ship compass has a translucent compass card and bowl and the card is illuminated from below. A hood for the binnacle is provided to protect the compass when not in use; the hood is provided with kerosene lamps for emergency use. A magnifying glass is provided which can be placed where it will give the helmsman a magnified view of that part of the card adjacent to the lubber's line and permit more accurate steering.

### *4412. Use of Compass in Hydrography*

Because of its location, the standard compass is less influenced by the vessel's magnetic field than the steering compass, and consequently its deviation remains more constant and can usually be reduced by compensation to smaller residuals. For this reason all long courses in navigation or hydrography should be set by the standard compass, the relative courses on the steering compass, by which the helmsman steers the vessel, being determined by simultaneous comparisons. The headings of the standard and steering compasses should be compared hourly when underway.

All bearings and deadreckoning depend on the compass heading for azimuth. In offshore hydrography the accuracy of dead reckoning between fixed positions depends directly on the course and the log distances, supplemented at times by astronomic sights.

The standard compass is usually installed on the flying bridge, or the deck directly above the pilothouse; and the steering or wheelhouse compass is in the pilothouse just forward of the steering station. Each is on, or parallel, to the centerline of the vessel and as far from magnetic metals as possible, and where the magnetic influences of the surrounding metals will be as evenly distributed as practicable.

Portable objects consisting of, or containing, magnetic metals shall not be allowed to remain in the vicinity of the compasses, for the magnetic field may be disturbed with a resulting change in the deviation. For the same reason, a vessel should not lie alongside a dock containing a large quantity of magnetic metal.

A compass shall be stowed face down when not in use, to preclude wear on its pivot.

For hydrography controlled by visual fixes or R.A.R., the vessel is steered by reference to the compass in an attempt to follow a chosen sounding line. The position of the vessel with reference to the line is determined by successive sextant fixes or bomb positions, and frequent alterations in course are made to bring the vessel back on the sounding line.

### *4413. Variation and Deviation*

For all practicable purposes the needle of the magnetic compass would point to magnetic north if influenced only by the earth's magnetic field. However, this condition is never attained on shipboard, except in specially constructed nonmagnetic vessels, as the ship itself sets up a magnetic field which causes the needle of the compass to deviate from magnetic north.

The *variation of the compass*, or *magnetic declination*, is the angle between true north and magnetic north, the latter being the direction assumed by a magnetic needle when acted on solely by the earth's magnetic field, that is, exclusive of any instrumental error and any effect of the ship's magnetism. The angle between magnetic north and the north indication of a ship compass on any particular heading of the ship is the *compass deviation* for that heading, and includes the instrumental error of the compass as well as the effect of the ship's magnetism.

Variation is called east or west according to whether magnetic north lies to the east or to the west of true north. Deviation is called east or west according to whether the north indication of the ship compass lies to the east or west of magnetic north.

Deviation varies for different compasses, different ships, different headings of a ship, for different geographic localities, and also if the ship is not on an even keel.

In converting compass courses to magnetic, and magnetic to true, easterly deviations and variations are always additive, and westerly deviations and variations are always subtractive for compasses graduated from 0° to 360°. In converting true courses to magnetic, and magnetic to compass, the signs are reversed. A convenient way to keep the signs straight is to think of the words—compass, magnetic, true—or true, magnetic, compass. If the words are in alphabetical order, apply the signs directly, if they are in the reverse of alphabetical order, reverse the signs before applying.

### *4414. Compensation for Deviation*

Compensation of the compass is the process of counteracting the effect of the ship's magnetism so that the residual deviations will be small. It is based on the general principle that the magnetic effect of the iron and steel of the vessel can be counterbalanced by magnets and soft iron placed near the compass.

Detailed instructions for compensating the compass are contained in Special Publication No. 96, and consequently the necessary operations are only briefly outlined here. Compensation should be performed only in comparatively calm waters, with the ship on an even keel, and with all movable iron or steel in its customary position as at sea. This should be done in a locality where the variation is accurately known. The operations enumerated below are for a Navy standard binnacle, but the principles are the same for any other type of binnacle:

(1) Set the spherical (*quadrantal*) correctors in middle position unless some other position is known to be more nearly correct. Place the heeling magnet in its tube, with its north (*red*) end up, unless it is known that the south end should be up, and lower it to the bottom of the tube. The magnet trays should be below the middle position.

(2) Steer magnetic north. Enter the athwartship magnets in their trays, placing the same number on each side, with their north (*red*) ends to starboard to correct easterly deviation, or to port to correct westerly deviation. Move the trays up or down until the ship's heading is north by compass.

(3) Steer magnetic east. Enter fore-and-aft magnets on both sides of the axis of the binnacle with their north (*red*) ends forward to correct easterly deviation and aft to correct westerly deviation. Move the trays up or down until the ship is heading east by compass.

(4) Steer magnetic south. If any deviation is found, compensate for half of it by changing slightly the position of the trays containing the athwartship magnets.

(5) Steer magnetic west. If any deviation is found, compensate for half of it by moving the trays containing the fore-and-aft magnets.

(6) Steer magnetic northwest. Move the spherical correctors toward or away from the compass, keeping them at equal distances from the center, until the ship heads northwest by compass.

(7) Steer magnetic northeast. If any deviation is found, compensate for half of it by moving the spheres slightly.

(8) Follow with a complete ship swing to determine the residual deviations. If the compensation is carefully and accurately performed, the maximum deviation for any heading should not greatly exceed 1°. A skilled navigator will set this as his aim. A ship swing before compensation is of value only for the information obtained with reference to the deviation and the amount of compensation required.

(9) At the first opportunity when the vessel is rolling freely, head on a northerly or southerly course. If heeling error exists, it will be most apparent on these courses. It will be indicated by abnormal oscillations of the compass. Raise the heeling magnet until the oscillation decreases or

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disappears. If it does not, try reversing the magnet in its tube. Careful steering is required, as the effect of yawing may be mistaken for that due to heeling error. The heeling error is due in part to the fact that the iron beams of the vessel are no longer horizontal when the vessel is heeled over.

(10) The compensation for semicircular and quadrantal deviation made with magnets and spheres will not hold good for all latitudes. If the vessel is operated in a considerable range of latitude, a Flinders bar will be required to compensate for changes due to change in latitude. The Flinders bar is usually located forward of the binnacle. Until opportunity is afforded to determine the exact length required, it is advisable to insert one of sufficient length to reduce the deviation on east and west headings to 10° before compensation, i. e., with the fore-and-aft magnets removed. A Flinders bar, so selected, will not entirely counteract the changes in the deviations due to change in latitude but will minimize them considerably.

### *4415. Determination of Deviation*

The principal methods of determining the deviation of a ship compass for various headings of the ship are:

(*a*) Bearings of the sun.
(*b*) Bearings of a range whose azimuth is known.
(*c*) Bearings of a distant object.
(*d*) Reciprocal bearings.

These methods are described in detail in Special Publication No. 96 and in the American Practical Navigator (Bowditch) and need not be repeated in this Manual.

(*e*) Another method is a modified form of method (*b*) in which neither the azimuth of the range nor the magnetic variation need be known and the two objects comprising the range need not even be charted. The ship swing is made as usual with both right and left rudder, the compass bearing of the range being measured as it is crossed on each heading. The two compass bearings of the range for identical headings are averaged. The mean values for all headings are then averaged and the difference between this average and the mean compass bearing for any heading will be the deviation of the compass for that particular heading.

A ship swing to determine the deviations of the compass shall be made at the beginning of each season's work, after a long lay-up period, after undergoing repairs at a shipyard, after a change of working ground involving a considerable change in latitude, and during the season if the deviations are found to differ appreciably from those on the deviation card. (See **144**.)

When swinging ship, the vessel must be on an even keel and the sea comparatively calm. To obtain the best results, good steering is necessary, and the ship must be steadied on each heading 2 to 3 minutes before the observations are made. The variation should be accurately known. It is printed on the compass rose of the chart for a particular locality, but should be corrected to the date of the swing by applying the annual change.

The deviation can be determined most accurately by swinging ship around the end of a wooden pier, if there are no magnetic metals in the vicinity. By using bow and stern spring lines the vessel can be warped around the sides and end of the pier and held stationary for the observations on each selected heading through 180°. Then the vessel must be turned around and the maneuvers repeated for the headings through the other 180°. The observations can be made on the sun or a distant object whose azimuth from the end of the pier is known or can be determined. Because the water is calm and the vessel can be held absolutely steady on each heading, an excellent swing should result.

A ship swing should not be made during a magnetic storm. The occurrence of these is unpredictable; they may last several days, are associated with sun spots and

the aurora borealis, and are world-wide in effect. The effect of a magnetic storm on a ship swing in low latitudes is practically negligible as the most severe storm will not affect the compass more than ½°, but in high latitudes the effect may be as much as 6° to 10°.

### *4416. Boat Compass*

The liquid type of boat compass has been adopted as standard by the Coast and Geodetic Survey. In general it differs from the ship compass only in size and portability. Various sizes, generally of 4, 5, or 6¾ inches in diameter, are used, the larger in auxiliary vessels and the smaller in pulling boats and ship launches. The cards are graduated in degrees clockwise through 360°, with no more than the cardinal and intercardinal points shown. A binnacle equipped with lights operated from the launch batteries or an oil lamp is provided for use at night. The 5-inch compass has been found most satisfactory for general use, especially in launch hydrography; a smaller compass is too sluggish and is generally unsatisfactory in a choppy sea and a larger compass is too cumbersome.

A boat compass can be mounted in a noncompensating binnacle near the steering station, or mounted on its box as a stand. It should be installed on the centerline of the boat. This line should be determined and the position selected for the compass station marked so that the compass can always be replaced in the same position. Other points to be guarded against in its installation are similar to those for the ship magnetic compass (see **4411**).

## 442. Gyrocompass

All modern survey ships of the Bureau and several of the older ships are equipped with Sperry gyrocompass systems, in addition to magnetic compasses. On a gyrocompass all directions are true, as the effect of magnetism is eliminated. There is no variation or deviation to be taken into account.

To ensure correct functioning of the gyrocompass it should be compared with one of the magnetic compasses at 15-minute intervals. At least once each watch it should be checked by an observation for azimuth on a celestial body. The result of this observation and one comparison with the magnetic compass each watch should be entered in a compass log book. Should any comparison indicate that the gyrocompass is not functioning properly, hand steering with reference to the magnetic compass shall be resorted to immediately and continued until the fault in the gyrocompass has been corrected.

In some installations it is not possible to set the steering and bearing repeaters closer than ¼°; in such case the relationship of the repeaters and the master compass for each trip should be recorded and the bearing repeater used for each bearing should be noted.

When the comparison between the gyrocompass and the magnetic compass differs consistently from normal by 1° or more for a short time, a local magnetic attraction may be indicated, and the possibility should be noted in the log book for future investigation.

### *4421. Theory of the Gyroscope*

A gyroscope is a well-balanced wheel, revolving at a high rate of speed, with freedom of motion about three rectangular axes. The phenomenon of the gyroscope is that its axis of rotation points in a fixed direction in space, if no outside force is exerted on it.

If the axis of a spinning gyroscope is in an east-west direction, as the earth rotates the axis will gradually tilt with reference to the horizontal.

Foucault's general law is that any freely suspended spinning body "tends to swing around so as to place its axis parallel to the axis of any impressed forces, and so that its direction of rotation is the same as that of the impressed forces." This principle is utilized in the gyrocompass. The rotation of the earth and the force of gravity furnish the forces which make the gyrocompass indicate true north.

Another characteristic of the gyroscope is called *precession*. If a force is applied to a spinning gyroscope, tending to change the direction of the axis, this force will not only be resisted but the gyroscope will turn slowly about an axis perpendicular to the one about which the force is being applied.

The precession characteristic is utilized to make the gyrocompass move to and settle on true north. A U-tube, partly filled with mercury, is mounted perpendicular to the plane of the gyroscope. As the earth rotates and tilts the gyroscope, if its axis is not in the plane of the meridian, the mercury flows in the U-tube to the low side. The force of gravity then exerts a downward force on that side, which causes the axis of the gyroscope to *precess* toward the meridian, where the tilt is corrected. This is a continuous effect, tending to keep the axis of the gyroscope in the plane of the true meridian once it has placed itself there.

### *4422. The Gyrocompass Equipment*

The gyrocompass is an electrically operated compass which is unaffected by magnetism and which automatically points very nearly to true north continuously. Small corrections for variations due to latitude, course, and speed are made semiautomatically. Once the latitude and speed corrections are set, no readjustments for changes of latitude of less than 3° or for changes of speed of less than 3 knots need be made.

A typical equipment consists of (*a*) a master compass, (*b*) a steering repeater, (*c*) bearing repeaters, (*d*) a course recorder, and often (*e*) a gyro pilot. The master compass is the principal unit; it indicates true north; the other units are auxiliaries for special purposes.

(*a*) The *master compass* is not used to steer by, nor is it generally installed in the pilothouse. It should be in a clean well-ventilated compartment, where heat is not excessive. For convenience and easy access it is generally located near the pilothouse. Advantages may be gained by having it near the center of gravity of the vessel. The lubber's line of the compass must be parallel with the fore-and-aft line of the vessel.

The master compass consists essentially of a gyroscopic wheel, mounted to spin on a horizontal axis and rotated electrically at high speed. The gyrocompass card is attached above the wheel and mounted with its 0° to 180° line in the same plane as the axis of the gyroscope and so that all movements of the wheel in azimuth are transmitted to the card.

A transmitter, to operate the repeater compasses, is attached to the frame which carries the lubber's line and is driven from a gear attached to the compass card so as to reproduce any movement of the card. The repeaters contain step-by-step motors through which the transmitter actuates them. Any number of repeaters can be operated.

The whole is housed in a binnacle for protection.

A detailed description of the construction and parts of the master compass is contained on pages 34 and 35 of Bowditch.

(*b*) The *steering repeater* resembles a compass in appearance, but it is a dummy, its card being synchronized with the master compass so as to repeat the movements of the compass card in the master compass. It is located near the steering wheel, mounted on an adjustable bracket so that its position can be changed to give a full view of the card from any position desired. All navigating is done from repeaters of which there may be several, one at each steering station.

(c) The *bearing repeaters* are similar to the steering repeater. There is usually one on each wing of the bridge, one on the flying bridge, and one installed in the radio direction finder. The repeaters on the wings of the bridge are mounted on stands and supported in gimbals. They are really gyro peloruses, and have the advantage that bearings taken with them are true bearings and do not have to be corrected for momentary deviations in course.

The repeater on the flying bridge is usually installed where it can be used for steering as well as for taking bearings.

The repeater installed in the radio direction finder is called a radio repeater. It is not mounted in gimbals.

(d) The *course recorder* is a repeater of a different form. It is usually mounted in a convenient location in the pilothouse. It preserves a graphic record of the actual courses steered and the times of all changes in course. It is synchronized with the master compass so that courses steered are graphically recorded in ink on a paper chart with a speed of about 1½ inches per hour. In addition to changes in course, yawing, poor steering, and the effect of weather on steering are automatically recorded.

(e) The gyro pilot is described in **4431.**

### *4423. Advantages and Disadvantages of the Gyrocompass*

Since the master compass alines itself in the true meridian, all courses and bearings registered by the various gyro repeaters are automatically *true*. Because the master compass is unaffected by the earth's magnetic field and the local magnetic forces within the ship itself, corrections for variation and deviation are eliminated.

There is little lag, as compared with a magnetic compass. More accurate steering is possible, even by hand, and less rudder needs to be used.

Disadvantages are that the gyrocompass needs a constant source of electric power to function. Storage batteries should be provided to supply automatically the deficiency for a time, if the ship's power fails. The mechanism must be put in operation several hours before it is to be used.

The mechanism is complicated and somewhat delicate, requiring repairs by experts should anything go wrong. Because of this, magnetic compasses must always be available for instant use if needed.

There is an error, of varying magnitude in different models, due to acceleration accompanying a change in course or speed. The acceleration exerts a force on the axis of rotation of the gyroscope and the compass starts to precess. This is a disadvantage in hydrographic surveying because the frequent 90° or 180° turns may start an oscillation of as much as 2° or 3°. The magnitude and duration of the precession depend on the period of oscillation and the amount of damping effect in each compass. Some gyrocompasses have a switch that can be turned just before such a maneuver to eliminate this difficulty more or less.

### *4424. Starting the Gyrocompass*

The master compass should be started about 4 hours before the ship leaves port, depending on its period of oscillation and how nearly in the true meridian it can be started. It should be set by hand as nearly as possible in the true meridian before the starting switch is pressed. This can be done by comparison with the magnetic compass or by the following method if the vessel is alongside a wharf or pier: After the vessel is tied up, switch off the repeaters first. This will leave them synchronized and they will also indicate the true heading, assuming the vessel does not move. Then in starting the master compass, it can be set with reference to the repeaters. After the master compass has run long enough to level itself, the repeaters can be switched in when the readings agree.

If the gyrocompass stops at sea, it is easier to set all repeaters in agreement on one heading and switch the master compass in, than it is to set each repeater separately.

There are two reasons for starting the gyrocompass several hours before leaving port: first, so that it may warm up to running temperature and to check its performance; and second, to give the master compass time to seek the true meridian. If it is started when it is within 2° or 3° of the true meridian, it should be close enough for all practical purposes in an hour or two.

On the working ground the gyrocompass shall be kept running in readiness for use at any time.

### *4425. Maintenance of Gyrocompass*

The gyrocompass needs no attention as long as it functions properly, except the periodic cleaning and oiling prescribed by the manufacturer. With each gyrocompass a large oiling and cleaning chart is supplied which should be mounted near the master compass. The cleaning and oiling is usually required at intervals of 3 or 4 weeks and may be done when the ship is in port and the gyroscope is stopped. All the exposed parts should be cleaned with a chamois skin or camel's hair brush even though no dust can be noticed. A few drops of oil should be added in the oil cups as directed. The oil vials on each side of the rotor must be drained and refilled with new oil from a medicine dropper to get the correct amount. It is important to have the oil level at the marks on the vials but not above them. Only that grade of oil prescribed by the manufacturer shall be used. If the oil turns green it should be changed more frequently.

## 443. COMPASS AUXILIARIES

Several auxiliaries are used in connection with the ship compasses in navigation and position finding. Of these, the gyro pilot and the photoelectric pilot are modern inventions, but the azimuth circle and pelorus are old and well known.

### *4431. Gyro Pilot*

The gyro pilot, or "Metal Mike" as it is frequently called, is an auxiliary for automatic steering used in conjunction with the gyrocompass. The gyro pilot consists of two units: the pilothouse unit at the steering station and the steering engine unit.

The pilothouse unit is connected with the master gyrocompass. It provides three alternative methods of controlling the rudder: fully automatic gyro steering, hand steering by the gyro pilot wheel, and manual steering with the automatic control disengaged. To change course the gear lever is moved from *automatic* steering to gyro pilot wheel steering and the vessel is brought on the new course by the use of this wheel. The rudder indicator must be observed closely because the pilot wheel should not be turned faster than the rudder will follow. One turn of the wheel gives approximately 8° of rudder. Changes in course of less than 10° are made by simply turning the gyro pilot wheel one spoke for each ½° change. The pilothouse unit may be adjusted by hand dials to improve the automatic steering performance in various weather conditions.

In automatic steering the steering engine unit is operated by a contact maker actuated by the master gyrocompass. The slightest departure of the ship from its course due to yawing, wind, or waves is counteracted by an automatic movement of the rudder in the opposite direction to bring the ship back on course.

### 4432. *Photoelectric Pilot*

The photoelectric pilot is a device for automatic steering in conjunction with the magnetic compass. There are three models of slightly different design for vessels of different sizes, although the same principle is embodied in each. The largest model is in use on the new auxiliary vessels of largest size. It is composed of the following five principal units:

(a) The *binnacle unit*, or directive element, consists of a high-grade magnetic compass of special construction, a simple light system, and a photoelectric cell, so arranged that the slightest deviation of the vessel from its course is detected and relayed to the steering engine unit. The binnacle unit is entirely automatic in operation. It is the brains of the pilot and performs accurately under all conditions of steering. It is entirely self-contained and requires no attention. Since it is not referred to in setting a course, it may be located in any convenient place in the vessel.

(b) The *steering engine unit* consists principally of the main casting, differential gearing assembly, motorized speed reducer power unit (electric), wheel-locking brake, limit switch assembly, and the drive to the tiller lines.

There are three gears in the differential assembly; the motorized speed reducer drives the first, the second being driven from the hand steering wheel, the drive to the steering cables being from the third member, or carrier.

In any differential gearing assembly, whenever one of the three rotating members is locked and either of the two remaining members is rotated, the one remaining free member will also be rotated.

For hand steering the first member of the differential is locked and the hand steering wheel is mechanically connected to the second member of the differential. Turning the hand steering wheel rotates the second member of the differential unit and this motion is imparted through the differential gears to the third member of the differential, or the carrier, from which the steering cables are driven.

For either power or automatic steering, the second member of the differential is locked, the electric circuit to the steering motor is closed, and the motor is operated in response to the impulse from either the automatic compass or the power steering control switch. Operation of the steering motor through the differential gearing moves the steering cables.

For power steering by hand, the steering motor operates at full power for rapid rudder movement, sufficient to move the rudder through an angle of 70° in 25 seconds.

In automatic steering the motor is automatically slowed down, for considerably less speed is required than in power steering. In automatic steering the hand steering wheel is locked and cannot be rotated. This safety feature prevents anyone from being injured by coming in contact with a rapidly revolving power-driven steering wheel as when the steering wheel shaft is driven directly from the steering motor.

Limit switches are mounted directly on the steering engine to stop the steering motor just before the rudder gets *hard over* in either direction. They are adjustable for any degree of rudder angle.

A roller chain sprocket from the third member of the differential moves the steering cables.

(c) The *electric control cabinet unit* is composed of the heavy-duty reversing contactors, transfer relay, motor speed resistance, sensitive relay and amplifier units, and the voltage divider unit. The contactors control the current to the steering engine motor. The transfer relay is an electromagnetic relay which transfers the control circuits from power steering to automatic steering and vice versa. The sensitive relay and amplifier units and the motor speed resistance are used only in conjunction with the automatic compass in automatic steering.

(d) The *pilothouse wheel, gear, and bearing unit* comprise the hand steering wheel shaft, the pilot power steering shaft and switch, and the switch control gearing.

The hand steering shaft is directly connected to the second member of the differential by a continuous roller chain and chain sprockets.

The photoelectric pilot power steering wheel drives a shaft with a worm and worm gear which operate the power steering switch. The rudder is moved by the steering motor in direct response to each movement of this pilot wheel. Centering this wheel causes the rudder to move amidships. Moving the pilot wheel halfway *hard over* to the right gives half-right rudder, etc. A rudder angle indicator indicates the actual rudder position at all times.

To place the pilot in the automatic steering position, the pilot steering wheel is centered and a push button switch is pressed. This energizes the transfer relay in the control cabinet causing the control to be shifted to the automatic compass.

To transfer control from automatic to power steering, the pilot steering wheel is moved either way off-center to disengage the transfer relay, causing the control to be shifted to the power steering position.

(e) The *automatic differential unit* is a small motor-driven differential connected in the drive between the steering engine and the binnacle unit. It is used only in automatic steering. Its function is to keep the automatic compass continuously alined with the magnetic compass while steering by hand with the pilot steering wheel so that when a change is made to automatic steering, the automatic compass will always be on the proper heading.

A smaller model is constructed and recommended for vessels between 50 and 100 feet in length. It has been installed on the new wire-drag launches *Hilgard* and *Wainwright*. It comprises three units: the steering motor with built-in clutch, the compass unit, and the electric control.

The steering motor unit may be installed in any convenient location where it can be connected by means of a sprocket and roller chain, so that when the clutch is engaged the steering motor actually operates the rudder system. The compass unit should be located where it is as free from magnetic disturbance as practicable. The electric control system is usually installed in the engine room.

A still smaller model is recommended for launches less than 50 feet in length. The motor, clutch, and electric control equipment are all combined in one compact unit to be attached directly to the steering wheel or somewhere in the steering system. The compass unit is separate.

### *4433. Azimuth Circle*

An azimuth circle is used on a compass or pelorus for the purpose of measuring bearings of terrestrial or celestial objects. It is essentially a metal ring which fits snugly around the compass in such a manner that it may be rotated horizontally with respect to the lubber's line. The ring is equipped with (*a*) a pair of sight vanes whose line of sight passes through the vertical axis of the compass; (*b*) a system of mirrors and prisms by which the point of the compass card cut by the vertical plane through the line of sight—in other words the compass reading—is brought into the field of view of the observer; and (*c*) another system of mirrors and prisms by which a pencil of the sun's rays is reflected on the compass card in such a manner as to indicate the bearing.

An azimuth circle should be tested occasionally for accuracy. This may be done by mounting it on a standard compass ashore at a place where the magnetic variation is accurately known. If the compass is otherwise unaffected a compass bearing of the sun should be the computed magnetic bearing at any instant and the difference between the two, if any, will be equal to the combined error of the compass and the error of the azimuth circle. There should be little measurable error in the compass, but any doubt in the matter may be eliminated by the use of two or more compasses.

A more accurate method is to test the azimuth circle on a planetable on shore, no compass being used.

On a piece of paper draw a circle slightly larger than the outside diameter of the azimuth circle. Two diameters of this circle are drawn at right angles to each other. Place the paper on the planetable and level the table carefully. Set the azimuth circle on the paper with the line joining the mirror and the prism coinciding with one of the penciled diameters. See that the bubble on the circle is in the center. If not, adjust it. Turn the planetable so that the sun's reflection from the mirror is directed through the prism and clamp the table. Adjust the table by slow motion until the pencil of light from the prism is reflected directly down on the penciled diameter. Now tilt the mirror slightly and see if the pencil of light follows along the penciled line. The azimuth of the sun will change very little in the time necessary to make this test. If the pencil of light follows the penciled diameter as the mirror is tilted, the azimuth circle mirror and prism are as nearly correct as any field test will show.

Now test the direct-vision vanes. First see if the line between them coincides with the penciled diameter at right angles to the one joining the mirror and the prism. By rotating the planetable, repoint the mirror toward the sun, then rapidly shift the azimuth circle 90° in azimuth on the penciled circle. If the direct vision vanes point accurately toward the sun, you may assume they are at right angles to the line joining the mirror and the prism.

If the azimuth circle, by this test, is found to be out of adjustment, it should be returned to the Washington Office for adjustment and another one requisitioned, unless the error is caused by a minor maladjustment which can be remedied in the field. Small errors in the direct-vision vanes can be corrected, but any displacement of the prism, caused by its being chipped or having been knocked out of adjustment, can scarcely be corrected satisfactorily except by a skilled instrument maker.

### *4434. Pelorus*

The pelorus, also called the Dumb Compass, consists of a circular flat metallic ring, mounted in gimbals on a vertical stand. One is usually installed on each wing of the bridge and on the flying bridge of the ship for use in taking bearings. The line between the center of the ring and the index mark must be parallel with the fore-and-aft line of the ship **(see 4437)**. The metallic ring is graduated from 0° through 360°, the same as the compass card, and can be revolved so that it can be set to correspond with the ship's course. Bearings are observed by means of a sighting vane which can be revolved horizontally by hand. A bearing by pelorus must be taken when the ship is exactly on course, or the ship's heading by compass must be read at the instant of observation and the pelorus bearing corrected for any deviation from the course.

Because of the damping of the oscillations there is a slight lag in the response of a magnetic compass. Precise bearings by pelorus referred to a magnetic compass are only possible when the ship is steady on course and the rudder is amidships. An observer should be stationed at the compass, whose duty is not only to read the heading at the instant of observation but to watch the wheel, rudder, ship's head, and the action of the compass for the most propitious moment.

When referred to the magnetic compass, bearings by pelorus must be corrected for variation and deviation to obtain the true bearing. Ships equipped with gyrocompasses have repeaters mounted in the pelorus stands so that all bearings observed are automatically true without corrections for the ship's heading, variation, or deviation.

### *4435. Telescopic Alidade*

More accurate bearings can be observed with an azimuth circle or a pelorus equipped with a telescope than are possible with an ordinary sighting vane. This is particularly true in hydrographic surveying where bearings are desired on buoys or distant objects, which are almost invisible to the naked eye.

The telescope should be of a low power with a large field of view which contains a vertical sighting line. The low power and large field of view are of great assistance in finding an indistinct object.

A telescopic alidade, which is available for use with the gyrocompass repeaters, resembles an azimuth circle on which is mounted an erecting telescope of about 3 power. It is arranged so that the part of the compass card vertically below the line of sight is reflected by prisms into the field of view. A level bubble is also reflected into the field of view. A rotatable prism may be attached for use in taking bearings of celestial objects; with it an object at any altitude can be reflected into the field of view while the telescope is kept level. Since the graduations of the compass card and the level bubble are in the field of view at all times, it is easy to read a bearing even when the ship yaws, rolls, or pitches so much that the telescope can be pointed at an object for only an instant.

Used with a gyrocompass, bearings are believed to be accurate to a half-degree even under moderately unfavorable conditions, that is, with a moderate sea and only fair visibility; and still more accurate under favorable conditions.

### *4436. Small Theodolite Used as a Pelorus*

A small 4-inch theodolite can be substituted for a pelorus with telescopic alidade with good results. The instrument should be mounted in a suitable location and be well secured. If the instrument tripod is used the legs should be well lashed to a ringbolt in the deck. The instrument must be oriented so that the 0° and 180° of the lower plate are alined parallel to the lubber's line of the compass (see **4437**).

On a distant object a rapid sequence of observations is made, the ship's head by compass being read at each "mark." The observations should extend over equal time intervals before and after the time of the position.

The observations should be made at approximately equal intervals, but it is more important that the ship and compass be steady at each observation than that a regular time interval be maintained.

Each observed bearing is applied to the respective compass heading, and the mean of the series is taken and corrected for the variation and compass deviation to obtain the true bearing.

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### *4437. Alinement of Pelorus*

A pelorus must be installed so that the line joining its index mark and the center of its dummy compass is parallel with the lubber's line of the ship compass, to avoid erroneous bearings. After the standard compass has been installed, the alinement of a pelorus may be tested, or a new pelorus oriented most accurately by simultaneous observations by pelorus and compass on a celestial body or distant object. The angle measured by pelorus should equal the difference between the compass heading and bearing. Every pelorus with which bearings for use in hydrography are to be observed should be tested in this way at the beginning of each season.

Any of the following methods may also be used, but with less accurate results, and they generally presuppose that the lubber's line of the compass is correctly alined with the centerline of the vessel:

(*a*) By reciprocal bearings between the standard compass and the pelorus. If the lubber's line of each instrument is parallel to the centerline of the vessel, the bearings should differ by exactly 180°.

(*b*) By computing the angle at the jack staff between the centerline of the vessel and a line to the pelorus. The pelorus is then set at this computed angle and the line of sight should pass through the jack staff. To compute the angle at the jack staff, find where a perpendicular from the pelorus intersects the centerline of the vessel, and measure the two distances. The distance from the point of intersection to the pelorus divided by the distance from the point of intersection to the jack staff will be the tangent of the desired angle.

(*c*) By equal offsets from the centerline while the vessel is stationary alongside a wharf. A point is located on the wharf or on shore which is on the prolongation of the centerline. The distance between the centerline of the vessel and the pelorus is measured. This distance is laid off from the point on the prolongation of the centerline. The index of the pelorus should pass through this point.

## 444. RADIO DIRECTION FINDER

A loop antenna attached to a radio receiving set receives an incoming signal at maximum strength when the plane of the loop is parallel to the direction of the incoming signal, and at minimum strength when its plane is perpendicular to the direction of the incoming signal. The change in intensity for a given angular rotation of the loop is more marked near the minimum than near the maximum. These characteristics are utilized in the radio direction finder to determine the direction of an incoming radio signal.

A radio direction finder, sometimes also referred to as a radio compass or radio pelorus, is basically a special type of radio receiver equipped with a loop antenna above the top deck of the vessel. The loop is mounted on a vertical shaft to whose lower end is attached a compass card. The loop can be rotated in azimuth.

Bearings are read from the compass card referred to the magnetic compass, in which case the ship's heading must be marked at each reading, or from a bearing repeater in connection with a gyrocompass system.

The radio receiver must give a relatively loud signal so that the minimum will be more sharply defined and should eliminate other undesired signals or interference.

Operating and maintenance instructions are supplied by the manufacturer with each instrument and should be followed.

### *4441. Use of Radio Direction Finder*

The radio direction finder is useful principally in navigation, and a bearing obtained with it is utilized just as a visual bearing is, and may be combined with other data to determine a ship's position. It is rarely of value in hydrographic surveying, for

at distances where it might be of use the results are not sufficiently precise. Any error is an angular one, increasing the linear error proportionally to the distance. Radio bearings may be useful as a last resort to fix the end of an astronomically controlled sounding line, when fog or other conditions prevent the use of more accurate methods.

Radio bearings are useful in navigation in clear weather as well as in fog. Collisions with passing vessels can be avoided in fog by observing their radio bearings and whether they change.

Certain radiobeacons operated by the United States Coast Guard have their radio signals synchronized with sound signals, so that, within audible range of the sound signal, a distance as well as a bearing from the station may be determined.

Unless the instrument is equipped with a gyro repeater, the helmsman or an observer must note the ship's heading at each bearing and each bearing must be corrected for the actual heading just as bearings by pelorus are corrected (see **4434**). If the minimum is indistinct or if the ship is yawing badly owing to heavy weather, the mean of several readings should be used.

### *4442. Radio Direction Finder Deviation*

Every part of a vessel and every object on board, capable of conducting electricity, has an electromagnetic field which affects the direction of the received signal in a manner similar to the effect of the ship's magnetic field on a magnetic compass. This error will differ for each bearing of the loop antenna with reference to the ship's heading.

Each instrument should be adjusted to compensate for most of the errors and the residual error should be determined for each position of the loop. This error is called the deviation and a deviation curve can be plotted similar to one for a ship magnetic compass.

The deviation is determined from a *ship swing* within sight of a radio transmitting station by taking several simultaneous visual and radio bearings on each heading. The transmitting station should be at the optimum distance for the visual and radio bearings, but never less than 1 mile. There should be little or no land between the ship and the station. Radiobeacons operated by the Coast Guard will broadcast specially for use in calibration if requested.

The differences between the visual bearings and the respective radio bearings, referred to the centerline of the ship, are the deviations of the radio direction finder for the various positions of the loop antenna. The visual bearings must be observed with great care since on them depends the accuracy of all future radio bearings. The ship's heading at each observation must be noted. The swing should be similar to that required for a magnetic compass.

The calibration of the radio direction finder should be made with the vessel in normal condition for sea, with all boats hoisted and movable objects in place. It must be borne in mind that changes in the positions of large metal masses, particularly if near the loop, may change the deviations of the instrument.

The values of the deviations should be verified occasionally by simultaneous visual and radio bearings.

Usually the maximum deviation will be where the plane of the loop is at a 45° angle to the fore-and-aft line of the vessel, and the minimum will be where it is parallel or perpendicular to the fore-and-aft line.

### *4443. Radio Bearings*

A radio direction finder is generally used to determine the bearing of a radio signal transmitted from a station whose geographic position is known. There are four general classes of stations whose bearings may be observed:

(*a*) Radiobeacons operated as aids to navigation by the Coast Guard. These operate continuously during fog or low visibility, and in clear weather during certain specified intervals. Each station emits a characteristic radio signal by which it may be identified by anyone without knowledge of the radio code. They are installed on lightships and near lighthouses where bearings to them will, in most cases, be entirely over water. The positions and characteristics of these stations and other valuable information are contained in the Light Lists of the United States Coast Guard, and in H. O. Publication No. 205, Radio Navigational Aids; their characteristics are also given on small reference radiobeacon charts published by the Coast Guard. All are charted on the nautical charts.

(*b*) The transmitters of direction-finder stations operated by the Coast Guard. These stations are primarily for furnishing bearings to vessels not equipped with radiocompasses, but bearings of their transmitters may be observed. A list of these with their call letters and characteristics and with the geographic positions of the transmitters is contained in H. O. Publication No. 205; other operational information is included. Similar information is in the Light Lists, except for the positions of the transmitters. All are charted on the nautical charts.

(*c*) Other federal and commercial shore radio stations near the coast, whose positions are known.

(*d*) Ships at sea.

For bearings on stations in (*b*), (*c*), and (*d*), except broadcasting stations, it is necessary to call the station by its radio call letters for identification and perhaps to get it to transmit.

It should be borne in mind that the published positions of stations in (*c*) are only approximate in many cases. Also such stations are likely to be inland from the coast and any intervening land may affect the direction of the received signal. It is best not to use stations in (*c*) unless they are known to be very near the shore.

### *4444. Accuracy of Radio Bearings*

In navigation, if three radio bearings intersect at a point, or nearly so, it may be generally assumed that a reasonably accurate position of the ship has been obtained. Less trust should be placed in radio bearings taken when conditions appear to be unfavorable, as for example, when they may be affected by excessive static, or by *night effect;* at such times they should be checked by repetitions and by any other means available. Radio bearings obtained with a radio direction finder on board ship may generally be considered to be correct within 2° if the following precautions are observed:

(*a*) Radio bearings should be observed by an experienced operator.

(*b*) The received signal should be sufficiently strong for the minimum to be clear cut and well defined.

(*c*) Radio bearings on stations more than 150 miles distant should be considered approximate.

(*d*) On some instruments the operator cannot tell whether he is measuring the bearing or its reciprocal.

(*e*) The deviation of the radio direction finder should be known accurately and applied.

(*f*) Unless a gyro repeater is used, the ship's heading should be noted at the instant each bearing is observed, and any correction applied. It should be noted that the accuracy of a radio bearing depends on the accuracy with which the ship's heading at the instant of observation is known. The same care is required as for bearings by pelorus or azimuth circle. If the heading depends on a magnetic compass, the accuracy with which its deviation and the variation are known also enters into the result.

(*g*) The bearing of a station, whose radio signal passes over land in reaching the ship, should be considered approximate.

(*h*) The bearing should not be taken of a station whose radio signal travels any appreciable distance along the shore.

(*i*) *Night effect* may be observed in bearings, particularly near sunrise and sunset. It is due to periodic unequal ionization of the air and may cause serious errors in bearings. It is usually manifested in a very wide or swinging minimum, so that the bearings seem to be changing while being observed. Errors due to night effect are not usually encountered at distances less than 30 to 50 miles.

### *4445. Radio Bearings on a Mercator Chart*

Radio bearings are arcs of great circles, or geodetic bearings, and, like them, must be corrected for the convergence of the meridians before being plotted on a Mercator chart. Only true north and south bearings, and true east and west bearings along the Equator, do not require this correction.

A table of corrections is published in the Coast Pilot; table 1 in Bowditch contains similar data. For distances less than 50 miles, the corrections are negligible.

It is important to apply the corrections with the proper sign. When bearings are taken from the ship and read clockwise, the sign of the correction is *minus* in north latitude where the ship is *east* of the radiobeacon and *plus* where it is *west*. In south latitude the signs are reversed. The signs are also reversed for bearings observed at the radiobeacon and radioed to the ship.

A radio bearing is always plotted *from* the position of the radiobeacon or fixed station since its position is known and charted. Consequently, if bearings are observed from the ship, 180° must be added after other correction.

For all practical distances radio bearings can be plotted without correction on Lambert projections.

## 445. Ship Logs

Ship logs are mechanical devices for measuring the distance or speed a vessel travels through the water. They are used extensively in navigation and in dead reckoning in hydrographic surveying. Logs are calibrated to register distance in nautical miles, or speed in knots. The revolution counter, although not a log, may be used for the same purpose, when properly rated.

### *4451. Patent Log*

The patent, or taffrail, log consists of a rotator towed through the water, the revolutions of the rotator being transmitted through the towline to a registering dial. The registering dial is sometimes installed on the rail at the stern quarter of the vessel, hence the name taffrail log; but for convenience in reading and to tow the rotator farther to one side of the wash of the propeller, it is often installed on the wing of the bridge, the towline being streamed from the end of a boom.

The rotator is a brass cone or spindle with spiral fins which cause it to rotate according to the speed with which it is drawn through the water. The logline or towline is a hard-laid type which does not snarl.

The rotator must be submerged at all times and towed far enough astern to avoid most of the effect of the propeller. The required length of towline varies, depending on the speed of the vessel and the height of the registering device. In general, for speeds up to 12 knots the length should be from 200 to 250 feet, and for 15 knots 300 to 350 feet. The best length for any vessel may be found experimentally by

steaming over a known distance. A new towline will stretch and it should be shortened to correct for this after having been used for a few hundred miles.

When the log is streamed, the line should be payed out gradually. During use, the register shall be oiled in accordance with the manufacturer's directions, which is usually once every 4 hours. The rotator must be handled carefully to keep the vanes from being dented or damaged in any way. The slightest dent in a vane will change the log factor appreciably.

When not in use, the log shall be carefully stowed in the box provided for that purpose. It shall be cleaned after each period of use to remove salt deposits.

There are also electric attachments which can be used to duplicate the readings of the registering dial in the pilothouse, or in any part of the vessel. This permits the officer of the watch to read the log himself instead of having to rely on a quartermaster or seaman who is sent aft for that purpose.

### *4452. Electric Submerged Log*

The electric submerged log is installed inside the hull of the vessel with a tube extending through the hull into the water. The motion of the vessel through the water turns a small rotator, whose revolutions are transmitted to a mechanism nearby, which is connected electrically to a registering dial in the pilothouse. The installation consists of a hull fitting and valve extension, or log casing, the submerged log mechanism and rotator, the distance indicator, and the electric connections.

Two makes of submerged logs, the Chernikeef and the Meridian, are installed on survey ships of the Coast and Geodetic Survey. In the most improved type of Meridian log the diameter of the rotator spindle has been increased and the entire log tube, the mechanism chamber, and the hub of the rotator have been filled with oil. The oil is kept at a pressure slightly exceeding the external pressure to prevent the entry of salt water. The dynamic pressure resulting from the ship's motion through the water is utilized to drive the oil through the spindle bearings of the mechanism. A signal light can be provided in the pilothouse to indicate that the oil in the log needs to be replenished or that water has entered the mechanism chamber. The oil should be renewed and the oil pressure maintained, and the mechanism should be cleaned and oiled, in accordance with the manufacturer's instructions.

The submerged mechanism should be drawn up into the hull when maneuvering in shallow water, near kelp or other marine growth, where there may be submerged logs, and at all times when not in actual use, to prevent fouling of, or damage to, the log mechanism. An appreciable change in the log factor is an indication that the apparatus may have become fouled.

The electric submerged log possesses the following advantages:

(*a*) There is no logline to be streamed, to be kept from fouling when the vessel stops, or to foul on survey buoys which are passed close aboard.

(*b*) There is no loss of distance when the vessel stops for vertical casts or for other reasons.

(*c*) Neither the state of the sea, the speed, nor the wake of the propeller affects the registration of the distances.

(*d*) The log, being beneath the bottom of the vessel, is clear of all floating obstructions and debris.

(*e*) The apparatus can be easily drawn inboard for inspection or attention.

(*f*) The registering dial is in the pilothouse where it can be read accurately and conveniently.

### *4453. Use of Logs in Hydrographic Surveying*

In ship hydrography controlled by dead reckoning or astronomic observations it is important to use two logs, which are read simultaneously to the nearest 0.01 nautical mile at each position. The mean of the distances given by the two logs, after their respective log factors have been applied, is used except when the results indicate that one has been functioning incorrectly. The use of two logs provides a check and is a safety factor in case one of them functions improperly.

When a taffrail log is used in ship hydrography, the ship's crew must be prohibited from throwing overboard rags or other materials which might foul the rotator.

### *4454. Calibration of Logs*

Logs shall be rated at the following times: at the beginning of each season's work; every 3 months during the field season if used to any appreciable extent in hydrography, except R.A.R.; and at any time there are indications that the rate of any log has changed appreciably.

A log factor is determined by comparing a distance as measured by the log with the true distance, assuming that no current has been encountered during the calibration run. This operation is similar to the calibration of the taut-wire apparatus described in **4467**, except for the disturbing influence of the current on log measurements. Any one of the four methods described in **4467** may be used to calibrate logs.

Logs should be rated at the speed of vessel at which they will be used. This will generally be the standard speed used in navigation and hydrography. (The extensive use of echo sounding has practically eliminated handlead sounding at slow speeds in areas where the use of a log would be necessary.) If it is expected that the logs will be needed for speeds other than standard speed, however, they should be also rated at the slower speeds. The taffrail and submerged logs and the revolution counter shall be rated on all runs made for determining log factors.

In determining log factors, the same precautions are required and the maneuvers should be performed with the same accuracy as in calibrating the taut-wire apparatus. In addition, certain other precautions are necessary, principally owing to the effect of the current on the log measurements. A calibration run must be started far enough from the beginning of the course to permit the taffrail logs to assume their normal rotation for that speed. Around turns taffrail logs follow an arc described by a shorter radius than that followed by the ship, and for that reason are rotating at a slower speed than normal at such times. The course to be followed during the calibration must be steered for several minutes before the initial end of the calibration distance is reached. A proficient helmsman must be at the wheel to steer a straight course throughout the run. The logs and the revolution counter must be read accurately and at the instant of the *mark*, and the times recorded.

Logs should preferably be rated where there is no current whatsoever, but such a condition is rarely obtainable. In an area where current is to be expected the calibration runs should be made at a time near slack water and the course selected should be parallel to the direction of the current. Cross-currents should be avoided.

A current which does not exceed 0.25 knot may be disregarded in log calibration runs. Stated in another way, when the difference between the log distances for consecutive runs in opposite directions is not more than 5 percent of the distance, the current may be ignored.

If the velocity of the current is too great to be ignored, the log factor must be obtained by solving simultaneous equations based on the two consecutive runs in opposite directions. The fundamental formula is

$$Ry \pm Tx = D$$

in which $R$ is the log distance, $y$ is the factor, $T$ is the time interval, $x$ is the velocity of the current, and $D$ is the true distance of the calibration run.

In using the formula it is assumed that the ship encounters an identical current throughout the double run. For this reason it is important that a calibration run in a current be made at a time when the current is constant, or nearly so, during the entire period of the double run.

Where the current is weak enough to be ignored, better results will be obtained if the calibration distances are comparatively long—at least 3 or 4 miles. In this case it should be sufficient to steam along the course three times, twice in one direction and once in the other direction. The mean of the first two runs may then be compared with the mean of the second and third runs to detect any blunders which may have been made.

Where there is enough current to be taken into account, the runs should be made along a shorter calibration distance—one of approximately 1 mile. In this case the complete calibration should consist of no less than three double runs. The reason for using a shorter distance where there is current is to shorten the time required for each double run so that there will be less likelihood of a change of current during it.

Log factors should be determined to three decimal places. Graphic scales for use in applying log factors during hydrographic surveying are described in **4827**.

## 446. Taut-Wire Apparatus

The taut-wire apparatus furnishes the most accurate means of measuring horizontal distances at sea. The apparatus is constructed so that a wire of small diameter, one end of which is anchored on the bottom, passes around a calibrated sheave as the ship steams along the route to be measured. The apparatus requires no motive power. If the anchor does not drag, the wire will remain stationary with reference to the ground, being drawn off the apparatus as the ship moves ahead. A unique feature of the design, adapted from submarine-cable laying equipment, is a revolving arm that unreels the wire from a large stationary reel so that the wire always remains taut.

The taut-wire apparatus was developed in England and has been used in hydrographic surveying by the Hydrographic Department of the British Admiralty since about 1921. The first apparatus acquired by the Coast and Geodetic Survey was installed on the ship *Oceanographer* in March 1933; others have since been installed on five other ships. The apparatus is an important factor in the position accuracy of recent offshore surveys and has made it practicable to extend accurate surveys to increased distances beyond the visibility of shore signals.

The manufacturer of the taut-wire apparatus, the Telegraph Construction and Maintenance Company, Limited, of East Greenwich, England, makes a large and a small-sized apparatus. They differ in operating principle as well as in the length of wire contained. The larger apparatus requires considerable space for installation and its use is limited to the larger ships; the smaller is more compact and is adapted for use on board small vessels.

### *4461. Description of Large Taut-Wire Apparatus*

The large taut-wire apparatus (fig. 75) consists of two principal parts, (1) a heavy standard *A* to which is attached a heavy reel *C* containing the wire, an unreeling mechanism *D*, and a brake and tension adjusting mechanism *E;* and (2) a long metal stand *B* which contains the measuring apparatus consisting of a cyclometer wheel *F* and revolution counter *G*, a dynamometer *H*, and suit able rollers and fair-lead sheaves to lead the wire over the measuring apparatus and toward the ship's stern.

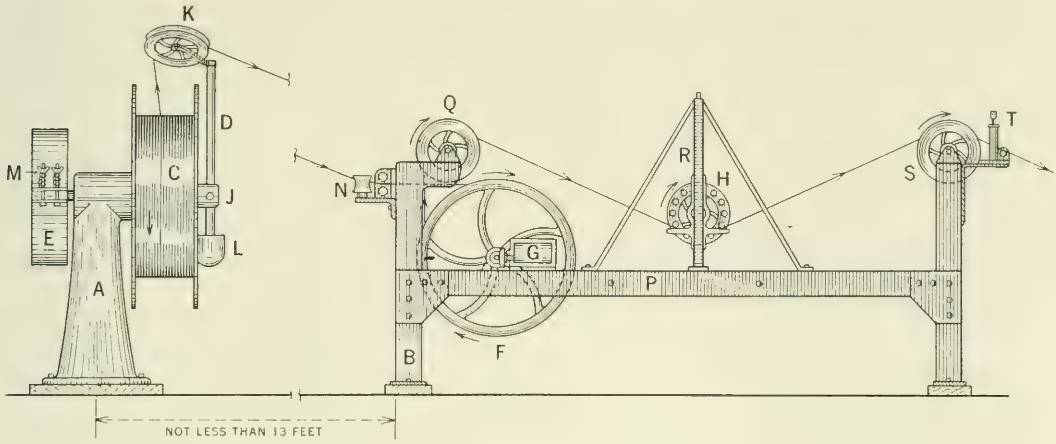


FIGURE 75.—The large taut-wire apparatus.

The standard *A* is permanently mounted on deck by through bolts to a structural member of the ship's hull. The standard has a horizontal spindle *J* to the after end of which is affixed a detachable flyer arm *D*, on one end of which a wheel *K* is mounted at an angle of about 45° with the axis of the spindle, and on the other end of which is a counterpoise weight *L*. A brake drum *E*, enclosed by a split brake band, is attached to the forward end of the spindle. The brake is operated by wing nuts *M* that work against springs on two bolts connecting the two sides of the band, which are used to adjust the tension on the wire. The flyer arm is detachable so that the reel, containing the wire, may be secured to and removed from a bracket on the standard. The reel is secured to the bracket by a center consisting of a central ring and three arms. The central ring is held to the bracket by a heavy setscrew and the end of each arm carries two setscrews that fit against a pad which engages a recess in the inner circumference of the reel. The center should be secured to the reel before it is attached to the bracket on the standard.

The reel, when fully wound, contains approximately 140 nautical miles of 0.0285-inch diameter (No. 21 B and S gage) piano wire having a tensile strength of approximately 190 pounds. The wire should not be galvanized for this would cause erratic operation of the apparatus. Any splices should be securely and neatly made so they will pass through the measuring apparatus without parting or catching. The reel must be mounted on the standard so that the wire will be unreeled by clockwise revolutions of the flyer arm.

The measuring apparatus is mounted on a metal stand which is slightly more than 8 feet long and 2 feet wide at the base. The forward end of the measuring apparatus contains two pairs of rollers *N*, mounted at right-angles to each other, whose important function it is to eliminate the rotary motion of the wire as it is unreeled from the reel. From between these rollers the wire takes a three-quarter turn around the circumference of the cyclometer wheel *F*, which is mounted between the horizontal members of the stand *P*. A six-figure revolution counter *G* registers each complete revolution of the cyclometer wheel. This wheel, over which the wire passes, is constructed with a circumference intended to equal one-thousandth part of a nautical mile.

The wire passes vertically upward from the forward edge of the cyclometer wheel, crossing the horizontal lead to the wheel, and over a fair-lead sheave *Q* mounted on the forward vertical member of the stand so that the wire will cross without interference. From the forward fair-lead sheave the wire passes under the sheave *H* of the dynamometer.

The dynamometer is an apparatus that indicates the tension of the wire. It consists of a sheave mounted in a frame *R*, that slides on two round vertical guide rods with springs at their lower ends. The frame is free to slide up and down on the guide rods and the tension on the wire is indicated by the position of a pointer attached to the frame relative to a calibrated scale on the forward side of the angle iron uprights. The wire passes around the lower side of the dynamometer sheave and from the lift of the sheave and frame, the tension on the wire is indicated on the scale.

After the wire leaves the dynamometer sheave it passes up over the after fair-lead sheave *S*, mounted on the after vertical member of the stand. Three rollers *T*, two vertical and one horizontal, are mounted aft of the fair-lead sheave and from between these, the wire passes into the water astern of the ship. If the wire does not lead fair into the water, additional rollers must be provided on the stern to lead it over the taffrail.

One spare reel is generally provided so that it may be sent to the wire manufacturer for refilling while the other reel is in use.

The operation of the apparatus is simple. After the end of the wire has been anchored and a tension has been placed on it by the ship's forward motion, the pull of the wire causes the flyer to revolve around the reel, lifting and unreeling the wire from the reel. The rotational velocity of the flyer depends directly on the forward speed of the vessel over the ground, and on a straight course over level bottom the length

of wire payed out will measure the true distance and be so indicated on the revolution counter, if it has been properly calibrated.

### *4462. Small Taut-Wire Apparatus*

The small taut-wire apparatus operates on essentially the same principle as the large apparatus but it is built in one compact unit that is very similar in appearance to a wire sounding machine. On each side of a sheet-metal base, 14½ inches wide by 35 inches long, are welded triangular-shaped supports, 21½ inches high, for a spindle, on which a reel with a capacity of 20 miles of piano wire is permanently mounted. A brake drum, fixed on the spindle, is partly surrounded by a band brake operated by a wheel mounted near the top of one of the triangular-shaped supports. A horizontal bar, pivoted above the center of the reel, has a cyclometer wheel geared to a dial-type of distance indicator on the after end and a spring balance on the forward end. This assembly forms a beam-type of dynamometer to measure the tension on the wire.

The distance is registered on a round dial having two concentric graduated scales each of which has a clock-like pointer hand. The inner scale is divided into 20 nautical miles, subdivided in tenths of miles. One revolution of the outer scale is equivalent to 0.2 nautical mile, divided and marked in hundredths of a mile and subdivided in thousandths, so that distances may be estimated to ten-thousandths of a nautical mile. An attachment is provided so that both pointer hands may be set at zero or as desired.

The lower end of the spring balance is attached by a metal rod to the base, and its upper end is suspended from the forward end of the horizontal bar. From the spring balance the tension on the wire may be read to half-pounds on a circular dial graduated from 0 to 100. When the apparatus is in operation the brake should be adjusted so that a tension of 36 to 40 pounds is indicated on the spring balance.

The apparatus should be installed and cared for and distances should be measured with it in much the same manner as described for the large taut-wire apparatus (see **4463**, **4464**, and **4466**). The operation of the apparatus is slightly different, for the reel revolves as the wire is payed out instead of remaining stationary as it does on the large taut-wire apparatus. Depending on the freedom with which the reel revolves, a heavier anchor may be required than is used with the large taut-wire apparatus.

The apparatus is prepared for use by reeving the wire from the bottom of the reel over the after side of the cyclometer wheel and three-quarters of a turn around it. The wire crosses below the cyclometer wheel, and is then passed under the fair-lead sheave on an arm attached to the after end of the base. From here the wire is lead over the stern of the vessel, through fair-lead rollers if necessary, and the anchor weight attached as explained in **4465**.

The reel is not removable and the wire must be wound on it on board ship. The wire should be wound on the reel under tension. It should be led from aft around the cyclometer wheel and under the fair-lead sheave on to the bottom of the reel. A manually operated attachment is provided at the base of the apparatus for use in winding the wire in even layers. A rope pully is attached to one end of the spindle so that power may be used and a crank is supplied for use in turning the reel by hand power.

There is insufficient clearance where the wire crosses under the cyclometer wheel; the wire coming off one side of the reel clears but will rub coming off the other side. Wire in one continuous piece should be used, but where splices are necessary they must be made securely and neatly, and they should be wound on that side of the reel where they will pass through the apparatus without interference.

The apparatus should be calibrated in the manner and with the accuracy described in **4467** for the large taut-wire apparatus. The instrument may be read to closer limits, however, and a measured mile course marked by shore ranges should be of sufficient length to determine an accurate calibration factor.

### *4463. Installation of Taut-Wire Apparatus*

The taut-wire apparatus must be installed near the ship's stern, and preferably where the wire, as it leaves the after rollers, will lead fair over the stern into the water. Such an installation is often impracticable, for the weight of the apparatus confines it to the main deck and the height of the taffrail often requires additional rollers to lead the wire over it astern. The two parts of the large taut-wire apparatus should be alined parallel to the centerline of the ship. There must be sufficient clear space between the standard and the measuring-apparatus stand for the flyer to revolve without interference, and a clear space aft of the apparatus for the wire to pass over the stern. A suitable location may generally be found on the quarterdeck or in one of the deck passageways between the house and the bulwarks. In the latter case, if there is a choice of sides, that side should be preferred where the revolution counter can be read most conveniently.

The standard and reel full of wire weigh approximately 3,000 pounds, so the standard must be mounted on a substantial foundation. The standard on a wooden base is bolted to the deck with 1¼-inch through bolts, engaging a structural member of the ship's hull. The axis of the reel must be parallel with the centerline of the ship. A special davit is furnished with the apparatus, to be mounted near the standard for use in handling the heavy reel, but it may not be required if the standard is located where a boat davit can be used instead.

The measuring-apparatus stand should be installed with its forward end not less than 13 feet astern of the standard (fig. 75). It must be installed so that it will be level when the ship is trimmed normally and on an even keel for the dynamometer to function properly. If the dynamometer is inclined, the frame will bind on the guide rods, restricting its vertical movement and preventing the registration of the true tension of the wire. The stand is generally fastened by bolts through the deck and mounted on thwartship blocks which are wedged on the outboard side, if necessary, to make the installation level.

If additional rollers are required on the stern they are generally improvised from material on board. They may be either permanently secured to the taffrail or mounted on a suitable piece of lumber to be lashed securely to the rail when in use.

### *4464. Care of Taut-Wire Apparatus*

The taut-wire apparatus is a comparatively simple mechanism and requires only ordinary care. All rotating parts are provided with grease cups or oilholes and they must be kept clean and well greased or oiled to ensure free movement. When the apparatus is idle, the flyer arm should be left in a position so that the hole in the lubricating ring is at the top. The brake drum should be lubricated with only two or three drops of light oil.

Light-canvas covers should be made and used to protect the apparatus when it is not in use. One may be made to cover the entire measuring-apparatus stand and another to cover the entire reel and standard, with provision in the latter to fit the flyer at the correct idle position, as described in the preceding paragraph. The wire on the reel must always be protected with several layers of oil-soaked cloth wrapped around the entire circumference, before the cover is placed on the drum standard.

The outer layers of wire are thickly greased by the wire manufacturers as protection from rust during shipment and storage. When a reel of new wire is first used this grease is quite annoying because the revolving flyer arm throws it in all directions, and some of it is carried to the revolving wheels where it is thrown on the deck and overhead. As protection from this the vulnerable parts of the ship should be covered with canvas or discarded tarpaulins, when a reel of new wire is first used.

### *4465. Preparation of Taut-Wire Apparatus for Use*

Each time before use all sheaves, rollers, and revolving parts of the taut-wire apparatus should be well lubricated. The grease cups should be removed, filled with a satisfactory grade of cup grease, and replaced. The parts requiring oil should be lubricated with a medium weight of engine oil. A special "Stauffer" lubricator, provided with the taut-wire apparatus, is used to lubricate the spindle of the standard. It must be screwed on the spindle lubrication hole after the brass hexagon cap has been removed. After the spindle has been filled with grease, the lubricator is removed and the hexagon cap replaced. After lubrication, all sheaves and rollers should be inspected and tested to ensure that they revolve freely.

The wire passes through the measuring apparatus as indicated by the direction of the arrows in figure 75. Before reeving the wire through the sheaves, the tension on the brake drum should be decreased by loosening the two wing nuts on the brake bands until the wire may be pulled off the reel by hand. The wire passes only three-fourths of a turn around the cyclometer wheel and care must be taken to pass it on the correct side so that the wire leaving the wheel clears the wire entering the wheel, where it crosses. After the wire has been rove through the measuring apparatus, it is led to the stern of the vessel and passed through the taffrail rollers, if these are used.

The end of the wire is then brought inboard and after sufficient slack has been pulled off the reel, the tension on the brake is increased and the wire made taut so that it will stay on the sheaves of the measuring apparatus. A length of Manila rope is secured to the end of the wire and the anchor weight is attached to the end of the rope. Any piece of scrap iron weighing from 65 to 80 pounds may be used for an anchor. The rope should be of small diameter but long enough so that the anchor may be lowered into the water by it. After the rope and anchor are attached, any slack wire should be reeled back on the reel by backing the flyer arm around the reel.

### *4466. Distance Measurements by Taut Wire*

Any distance at sea may be measured by taut wire. The taut-wire apparatus was especially designed to measure horizontal distances between buoy stations, and its principal use is for the measurement of distances between stations in a buoy traverse.

During a taut-wire measurement only one man is required to attend the apparatus constantly, but two observers are required to read the revolution counter when a "mark" is given. The taut-wire attendant stands by the apparatus on the alert to see that all parts function properly and to maintain the correct tension on the wire. He also gives the "mark" when the station is abeam, so that the observers may keep their eyes fixed on the revolution counter at this critical instant. At the "mark" both observers read the revolution counter and agree on the reading before it is recorded by one of them in a taut-wire book—any type of small blank book will serve—the other observer verifying the recorded reading. After a distance has been measured, one of the observers takes the difference between the two revolution-counter readings and reduces it to meters by multiplying it by the factor (see **4467**), the other observer checking the result; after which the taut-wire readings, difference, and distance are entered and checked in the appropriate spaces on Form 777, Taut-Wire Traverse Observations, which is kept on the bridge.

The officer-in-charge, who is on the bridge conning the ship and maintaining it on range, is assisted by another officer who observes certain data and records all data on Form 777. In addition to the taut-wire measurement, Form 777 contains columns for the following information: The name of the buoy station, the time it was passed abeam, the log reading when abeam, the difference in log readings between two consecutive buoy stations, the depression angle to the station if one was measured, the distance passed abeam, the side of the vessel on which the station was passed, the direction of the current, and three columns in which the azimuth between stations is to be recorded. In the column headed "Current Direction" the estimated velocity of the current should also be entered. Some of the vertical columns are ruled with two horizontal spaces opposite each buoy station, one of which is marked with a buoy symbol, the other being marked with an anchor symbol. If the data have been observed to the buoy structure, as they usually are, they should be entered in the horizontal space opposite the buoy symbol, the space opposite the anchor symbol being reserved for the comparatively rare cases where special arrangements are made for observing the data directly to a small buoy marking the anchor position (see **943**).

The officer assisting on the bridge enters all the observed data except the taut-wire data, the latter being entered and checked by the observers at the taut-wire apparatus. He is assisted in the observations by the officer-in-charge and the quartermaster on watch, for all of the required observations at each buoy must be made almost simultaneously. The direction and velocity of the current can usually be observed shortly before or after the station is abeam, but the time, log reading, and distance abeam must be obtained simultaneously at the instant the observation station on the bridge is abeam of the station. The direction of the current must be recorded as the direction toward which the current is flowing. This is usually the reverse of the observed bearing since the ship usually passes on the down-current side of the station (see **2512**). The azimuth between stations is generally observed some time before the first station is abeam, although occasionally it has to be observed in the reverse direction after the second station has been passed. In the latter case it should be recorded as observed, with the station names recorded in the observed order from the near to the far buoy.

After the taut-wire apparatus has been prepared for use (see **4465**), the ship is maneuvered to a position near the extension of the range between the two stations marking the distance to be measured. The ship's heading should be approximately that of the azimuth of the range, the distance from the nearer station depending on the depth of water (see **4468**). The ship is either slowed to mere steerageway or stopped completely while the taut-wire anchor is released.

Two men are required when the anchor is lowered. One man lowers the anchor into the water ready to be dropped, while the other man attends the brake of the taut-wire apparatus by which the anchor is held suspended. The signal to drop the anchor is given by the bridge; it is usually one short blast of the whistle unless other ships are in the vicinity, when the loud-speaker system or a messenger should be used. At the signal, the taut-wire attendant releases the tension on the brake, allowing the anchor to descend slowly to the bottom, and notifies the bridge when the anchor strikes bottom.

After the anchor is on the bottom the ship moves slowly ahead, gathering speed very gradually to avoid dragging the anchor. A ship equipped with pilothouse speed control is best adapted to measure distances with the taut-wire apparatus, for the rate of increase in speed can be controlled on the bridge. If the speed is controlled by telegraph signals to the engine room, a routine must be established for increasing the speed gradually and steadily at such times. The engineer on watch should be notified whenever a taut-wire measurement is to begin and how many minutes he should use in working up to standard speed. The engines should be started very slowly and thereafter the officer-in-charge need only notify the engine room when he judges the speed is being increased too fast or too slowly. The maximum speed on a taut-wire measurement should not exceed 9 knots, for the revolution counter of the instrument is difficult to read accurately at greater speed. As the speed is increased the taut-wire attendant must increase the brake tension gradually until at standard speed a tension of 36 to 40 pounds is indicated on the dynamometer scale. If the sea is rough and the ship rolls considerably, the tension should be adjusted near the lower limit in order to avoid excessive strain on the wire and the risk of dragging the anchor.

The ship is steered on the range toward the first buoy station, but when it is near, the course is altered slightly so as to pass it on the down-current side at a distance of 15 or 20 meters. When the ship is within approximately 400 meters of the buoy, the officer-in-charge on the bridge must notify the personnel at the taut-wire apparatus to stand by on the alert to read the revolution counter. They may be notified through the loud-speaker system or, if no other ships are in the vicinity, by very short blasts of the whistle in conformity with the passing signals of the Rules of the Road; one short blast if the station is to be passed to port and two short blasts if it is to be passed to starboard.

The two observers, assigned to read the revolution counter, stand by while the approach to the station is watched by the taut-wire attendant, who should station himself where he can give the "mark" to read the revolution counter when the station is abeam. A deckhouse or any thwartship structure conveniently located may be used for alinement to mark the station when it is abeam. All the stations in a consecutive measurement should be marked from the same position.

The accuracy of a taut-wire measurement depends on the maintenance of a straight course throughout the distance to be measured. A taut-wire measurement is always simplified if the traverse stations have been anchored approximately in a straight line, for the ship may then be kept on course by the use of the forward range. Where a

measurement is made between only two stations or between the last two stations of a traverse, the azimuth of the far station should be measured when the ship is abeam the first station and the far station kept on this azimuth until it is approached. This will ensure the maintenance of a straight course between the two stations.

Where long distances are measured between two stations which are not intervisible, the course between them must be carefully computed and allowance made for the current indicated at the first station by the lead of the anchor cable. In R.A.R. surveys, positions may be obtained at regular intervals along the line so that the course may be altered slightly to maintain the ship on line. If a long distance between two sono-radio buoys is being measured, bombs fired at intermediate positions, to measure the travel time of sound, give valuable data for the study of the velocity of sound (see **6351**). When the far station is finally sighted the course should be altered immediately to pass the station at the desired distance. If the course has been carefully determined, or if the ship has been maintained on line by fixes, a change in course of no more than 2° or 3° should be necessary to head toward the station. The direction of the current at this station may be assumed to be the same as at the first station, until the ship is close enough for the direction to be observed, when a further change in course must be made, if necessary, to pass the station on the down-current side.

The wire should be cut immediately after passing the last station in a taut-wire measurement. A straight section should be selected, preferably aft of the measuring apparatus. It may be cut by holding a piece of metal under the wire, while it is tapped with the sharp edge of a chipping hammer or other sharp tool. The cyclometer wheel revolves rapidly after the wire has been cut, and in order to keep a record on the revolution counter of the total amount of wire used, so as to estimate the amount remaining on the reel, the wheel should be stopped immediately by a slight pressure against its side.

A taut-wire measurement should never be started so late in the afternoon that there is a chance of not completing it before dark. Neither should a measurement be started when there are indications of fog, which may close in to obscure the far station from view. Taut-wire measurements may be made during comparatively rough weather, but it should not be so rough as to prevent an even tension being maintained on the wire.

### *4467. Calibration of the Taut-Wire Apparatus*

The cyclometer wheel of the taut-wire apparatus is made with a circumference approximately equal to 1.853 meters, so that 1,000 revolutions are equal to 1 nautical mile. This circumferential length cannot be accepted as exact, since it varies slightly with each taut-wire apparatus and changes with use as the wheel wears slightly. It must be accurately calibrated to determine the correct factor to reduce the distance, measured in revolutions, to meters. The apparatus should be calibrated at least once annually and at any other time when there is reason to believe that the factor being used is incorrect. The factor may be determined either by direct measurement of the circumference of the wheel or by the indirect method of determining the number of revolutions of the wheel required to measure with the wire a sufficiently long distance, the length of which is accurately known or may be determined from simultaneous observations.

The circumference of the cyclometer wheel may be measured directly by stretching a piece of the wire around the wheel. About 18 inches of each end of the wire should be annealed and a sufficient length should be used so that one end may be made fast

while a spring balance is attached to the other end. The wire is led one turn around the wheel, lapped 3 or 4 inches and stretched with a tension of 36 pounds indicated on the spring balance. A scratch, parallel to the axis of the wheel, is then marked across the two lapped parts with a sharp tool. To measure the circumference, the wire is stretched on a flat surface with the same tension and the distance between marks measured with a beam compass and meter bar. Since the distance is more than a meter, an additional scratch must be made near the middle of the length and each part accurately measured. The complete procedure should be repeated several times, using a different piece of wire for each measurement, and the mean of the results is used as the calibration factor. A factor so determined is sufficiently accurate if only short distances are to be measured with the apparatus, but where long distances are to be measured a calibration by indirect measurement should be made.

The indirect method is the reverse of measuring a distance with the taut-wire apparatus. Wire is laid by the apparatus along a distance of accurately known length, and the known distance divided by the number of revolutions of the cyclometer wheel gives the desired calibration factor. The measurement for calibration is made in exactly the same manner a distance is measured (see **4466**) but at a slightly slower speed in order that the revolution counter may be read very accurately. If the distance is of sufficient length it need be measured in only one direction. No change in course should be made during the calibration run.

Any taut-wire measurement may be in error by one revolution of the cyclometer wheel, because only whole revolutions are recorded on the counter; since the circumference of the wheel is approximately 0.001 nautical mile, there may be an error of 1 part in 1,000 in a measurement of 1 mile. To reduce this error, the calibration factor should be determined from a distance of at least 5 miles, if the apparatus is to be used to measure long distances, such as those required in R.A.R. surveys and distances to locate a station beyond the visibility of shore signals (see **2532**). A measured mile speed course should not be used because of its shortness; neither should the distance between two buoys be used because of the error in distance which may be introduced by the scopes of the anchor cables. The following methods of calibration have been found satisfactory and one of them will generally be found practicable in most localities:

(*a*) The wire may be laid along the straight course between beacons erected in the water, which have been located by triangulation. Either an accurate distance between them is available or may be derived from an inverse position computation.

(*b*) The ends of a calibration run along a selected course may be determined by three-point sextant fixes observed to shore triangulation stations. The fixes must be strong and the sextant angles must be accurately measured; each fix should be checked by a third angle. Three successive fixes with simultaneous readings of the taut-wire revolution counter should be obtained at each end of the line. The accuracy of the calibration may be increased if the run can be made where a range may be steered. The positions fixed by sextant and the distances between them should be computed. The accuracy of the position determinations may be gaged by studying the residual distances between the three positions at each end of the line.

(*c*) On a thickly settled coast it is occasionally possible to find four objects, located by triangulation, which may be used as two ranges, normal to which a calibration run of sufficient length may be made. The four objects should be selected so that the azimuths of the two ranges are approximately the same. A buoy should be anchored with a short scope at a sensitive position on each range and the position of each buoy determined by a three-point sextant fix, from which its distance from the respective front range may be determined. The buoys are used as leading marks and from their positions the azimuth of the course to be steered is computed. On the calibration run the revolution counter is read as the range is crossed and a depression angle is measured to the buoy as it is passed. The depression angle distance is applied to the distance of the buoy from the front range to obtain

the distance of the ship from the front range when the range was crossed. From these data the distance run by the ship between the two range crossings may be computed for the true azimuth of the course traversed.

(*d*) The wire may be laid along a range, where there are two lighthouses or landmarks within a half-mile of the range and at a suitable distance apart. The positions of the two range marks and the other two objects must have been determined by triangulation. The distance along the range between the two objects, when each is normal to the azimuth of the range, may be computed. On the calibration run the revolution counter is read when each object bears 90° from the range, this being determined by an observer with a sextant set at 90°, who marks the instant when each object is exactly abeam.

For best results the taut-wire apparatus should be calibrated in a locality with a type of bottom similar to that over which it is to be used to measure distances, but this is seldom possible. A truly horizontal distance should be used for calibration, so an area should be selected where the bottom is comparatively level and free from shoals and depressions, and preferably the depth should not exceed 20 fathoms.

### *4468. Accuracy of Taut-Wire Measurements*

The closure errors of loop traverses in the past indicate that an accuracy of about 1 meter per statute mile or, roughly, 1 part in 1,600 may be expected from careful taut-wire measurements. To obtain this accuracy the apparatus must be operated and the data observed and recorded with extreme care. There are sources of errors not in control of the ship personnel, however, which may cause inaccuracies.

The angle with which the wire leads over the stern can, of course, be observed, but nothing is known of the trend that the wire takes below the surface of the water nor at what distances astern of the ship the wire will rest on the bottom in various depths of water and under different tensions. It is apparent that a true horizontal distance will not be measured if the angle of the wire leading over the stern is appreciably different at the two ends of a taut-wire measurement, but if this angle is the same at both ends it is probable that, within measurable limits, a true horizontal distance will be measured. In depths to 20 or 30 fathoms a preliminary run of ¼ mile, or even less, with the recommended tension applied and stabilized before the first mark is reached should ensure the same lead angle throughout the measurement, provided a uniform tension is maintained and provided the depths are fairly uniform. In depths greater than 100 fathoms a preliminary run of from 1 to 1¼ miles is generally required.

If the fixed end of the wire is secured by some means on the surface of the water but the wire is not buoyed at intervals as it is payed out, a true horizontal measurement will be obtained for only a very short distance; as the wire is payed out its weight will cause it to hang in a catenary curve until the center of the curve touches the bottom. The measured distance will not be a true horizontal one, as an error will be introduced which will vary with the depth of water. A taut-wire measurement started with the wire anchored on the bottom, where the depth of the water differs considerably at the two ends of the course, will likewise be in error; but a more accurate result will be obtained if the measurement is started in the deeper water.

Irregularities in the depth of water between the two ends of a distance measured by taut wire prevent the measurement of an accurate horizontal distance. If the distance is sufficiently long, the wire will lie on the bottom for most of the length, and the distance measured, instead of being horizontal, will be along the bottom profile. Prominent shoals and deep submarine valleys will introduce appreciable errors in the measurement.

The amount of resistance offered by the water to a side pull on the taut wire when a change in course is made is not definitely known. Observation indicates a great resistance and probably changes in course as large as 10° or 12° can be made at buoys in a traverse line without introducing appreciable errors in the measurements. Sometimes it is practicable to pass outside of a buoy on a sharp turn to ensure that if the wire is pulled sidewise it will be stopped by the buoy cable. This should not be done at a sono-radio buoy, for the wire may foul the hydrophone. When appreciable changes in course are made during a taut-wire measurement between two buoys, especially where long distances are involved, the measured distance must be reduced to the true distance between marks.

The expansion, or contraction, of the wire after it passes into the water probably does not cause any appreciable error. The coefficient of expansion of the wire is such that a temperature difference of 1° C. between the temperature of the air and water will change the length only 0.024 meter in 1 nautical mile of wire. For the differences in temperature ordinarily encountered and for the usual distances measured this may be neglected.

## 45. NAVIGATION AND POSITION-LOCATION INSTRUMENTS

This section describes the most important navigation and position-location instruments used on survey ships, auxiliary vessels, and launches of the Coast and Geodetic Survey, and their care and use in navigation and hydrographic surveying. Included are such instruments as sextants, protractors, and chronometers. Theodolites, alidades, and similar instruments are not described in this Manual.

### 451. SEXTANT

The sextant is a portable instrument for measuring the angle between two objects. It is universally used on shipboard by the hydrographic surveyor and is one of the most important instruments used in marine navigation. With it the hydrographer afloat makes most of the measurements for which a transit or theodolite is used ashore. In hydrographic surveying the sextant is used principally to measure the horizontal angle between two terrestrial objects or survey buoys. It is by this means that the three-point problem is used in hydrographic surveying for locating the position of the survey vessel at selected times during the sounding. The sextant is also used extensively to measure the altitude above the horizon of celestial bodies; to measure inclined angles to celestial bodies to obtain azimuths; and to measure small vertical angles from which distances are obtained.

A sexant consists of a light rigid framework *DAF* (fig. 76), usually of brass or some similar alloy, which carries a limb or arc *DF* in which is inlaid a strip of silver on which the arc is graduated. On the underside of the sextant are usually three legs by which the sextant may be supported on a table, and a wooden handle by which it is held when measuring angles. An index arm *AE* carries the index mirror *A* which is perpendicular to the plane of the sextant. The index arm is pivoted at *A* so that it can be rotated in the plane of the instrument from *D* to *F*. The lower end of the arm is provided with a means for clamping it at any position on the limb, a tangent screw for slow motion, and a vernier *E* for more accurate reading of the measured angles. A magnifying glass is attached to the index arm for use in making the readings.

At *B* is another mirror, called the horizon mirror, which is also perpendicular to the plane of the sextant. At *C* is a small telescope with its axis fixed in the line *CB*.

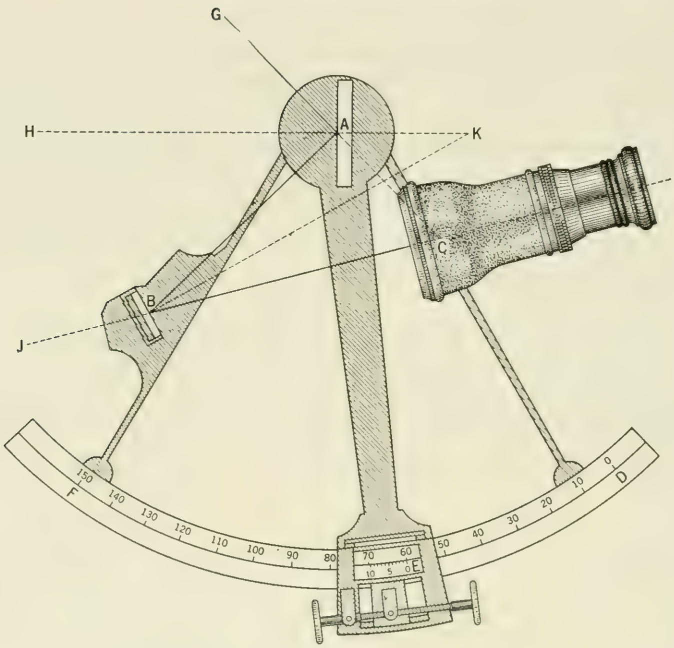


FIGURE 76.—Optical principles of a sextant.

## *4511. Principles of the Sextant*

The construction of the sextant is based on two simple principles: *First,* the optical principle that the angle of incidence equals the angle of reflection in a plane which contains the normal to the reflecting surface at the point of reflection. In a sextant (fig. 76) the image of an object at $G$ is reflected by the index mirror $A$ so that the angle $GAH$ is equal to the angle $HAB$, the line $HA$ being the normal to the surface of the mirror $A$. Likewise, the angle $ABK$ is equal to the angle $KBC$. *Second,* the geometric principle that when a ray of light undergoes two successive reflections in the same plane, the angle between its first and last direction is equal to twice the angle between the reflecting surfaces. From this principle the angle $JCG$ is equal to $2BKH$. The angle $ABC$ is a constant for any sextant.

In the sextant the index mirror $A$ is carried on the index arm $AE$. It follows, then, that if the mirrors are so arranged as to measure an angle of 0° when the index arm is at $D$, any angle such as $BKH$ resulting from a movement of the index arm must equal the angle $DAE$.

But according to the second principle the angle $BKH$, and consequently the angle $DAE$, is equal to one-half of the measured angle $JCG$. The limb or arc of the sextant is therefore graduated so that any angle such as $DAE$ may be read at double its value or the equivalent of the angle $JCG$.

## *4512. Navigating Sextant*

As the name implies, a true sextant is limited to one-sixth of a circle, so that the maximum angle that can be measured with it is 120°. The instruments, almost universally known as sextants, are actually quintants, constructed for the measurement of angles up to 144° or slightly larger.

Two types of sextants are used by the Coast and Geodetic Survey. The larger and more precise is a navigating sextant, sometimes called an astronomic sextant. The arc of this sextant has a radius of approximately 7½ inches, or 19 centimeters. It is constructed so that angles up to approximately 144° can be measured with it. The arc is graduated by divisions 10 minutes apart, but by means of a vernier it can be read to the nearest 10 seconds. The average navigating sextant weighs approximately 3⅓ pounds.

All navigating sextants now acquired by the Bureau are equipped with binocular-type telescopes with a magnification of about 3½ diameters. The telescope can be focused and is removable but is provided with no adjustment.

Each navigating sextant is provided with two sets of colored shade glasses installed so that one or more of one set can be interposed in the direct line of sight and one or more of the other set in the reflected line of sight. Their purpose is to reduce the brightness of the rays of light from the sun and sometimes the horizon. The two mirrors used on the navigating sextant are slightly larger than those used on the hydrographic sextant.

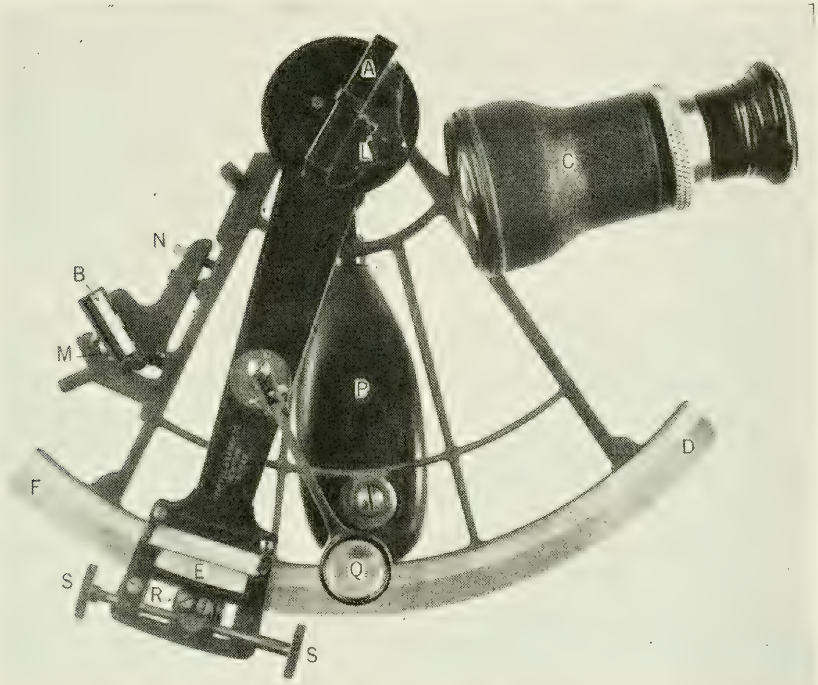


FIGURE 77.—Principal parts of a sextant. *A*. Index mirror. *B*. Horizon mirror. *C*. Telescope. *DF*. Graduated arc. *E* Vernier. *AE*. Index arm. *L*. Index mirror adjusting screw. *M*. Screw to adjust horizon mirror perpendicular to plane of sextant. *N*. Screw to adjust horizon mirror parallel to index mirror when index arm is set at zero. *P*. Wooden handle. *Q*. Attached reading glass. *R*. Clamp screw. *S*. Tangent screw.

### *4513. Hydrographic Sextant*

To provide steadiness during observations, a sextant should be as heavy as practicable without tiring the observer or causing him discomfort. Since a hydrographic sextant is used continually in hydrographic surveying, it should be lighter in weight than a navigating sextant. It may also be smaller since the accuracy of a navigating sextant is usually not required in hydrography.

Hydrographic sextants (fig. 77) used by the Coast and Geodetic Survey are similar to the navigating sextant, except that they are smaller in size and weight, the arc usually having a radius of about 5¾ inches and the sextant weighing about 2¾ pounds. The arc is graduated in half-degrees, but angles can be read to the nearest minute by means of a vernier. Like the navigating sextant, each is fitted with a binocular telescope of 3½ diameters magnification.

The mirrors of the hydrographic sextant are slightly smaller in size than those of the navigating sextant. Hydrographic sextants are either not provided with shade glasses or they are removed before use.

Hydrographic sextants are often constructed so that the maximum angle that may be read on them is slightly larger than on the navigating sextants; depending on the construction, angles between 144° and 151° can usually be read.

### *4514. Sextant Mirrors*

There are two mirrors on each sextant. The index mirror *A* (fig. 76) is held in an adjustable frame on the arm *AE* and is so called because it is attached to the index arm and rotates with it. It is the larger of the two mirrors and its entire area is a reflecting surface. The other mirror *B* is called the horizon mirror because it is through, or above, it that the observer sights at the horizon when measuring the altitude of a celestial body. This mirror is considerably smaller than the index mirror. It is also held in a frame, which is provided with two adjustments. Formerly, this mirror was a glass of which only the lower half was a reflecting surface, the observer looking through the clear upper half directly at one of the objects. In the Coast and Geodetic Survey, only the reflecting portion of the glass is used, the observer sighting over it at the direct object.

Formerly, all mirrors were of glass, the reflecting surface consisting of silver deposited on the back of the mirror.

A fresh chemically deposited silver surface has an exceptionally high reflectivity, approximately 90 percent, but it tarnishes readily and is easily scratched. When the reflecting surface is on the reverse side of the glass and the light rays must pass through the glass twice, the reflectivity is reduced in varying amounts, probably resulting in an average reflectivity of 80 percent.

The reflectivity of highly polished stellite is 67 percent and that of highly polished stainless steel is approximately 61 percent.

*a. Glass mirrors.*—Stellite mirrors are used almost exclusively in hydrographic surveying in the Coast and Geodetic Survey, but due to the higher reflectivity of the best glass mirrors their use may still be desirable for some purposes.

Glass mirrors must be optically flat and their two surfaces must be within 2 seconds of parallelism. The glass reflects from its front surface as well as from the mirrored surface. If the two surfaces are parallel the reflected images from the two will coincide in the telescope to produce a single image, but if the two surfaces are not parallel there will be two images or a distorted image which may appear as though it were out of focus. If the reflected object is a star it will appear enlarged or elongated. Sextant mirrors with these characteristics should not be used for accurate observations but should be returned to the Washington Office with a report of the defect.

The error due to a prismatic index mirror will vary with the size of the angle measured. The error due to a prismatic horizon mirror, however, is a constant and is included in the index correction. Consequently, if the effect of the latter is not otherwise disturbing it need not be replaced.

When a glass mirror is inserted in its holding frame, the screw at the back of the frame must not be tightened so much as to introduce a torsion in the glass.

The greatest disadvantage of glass mirrors is the rapid deterioration which takes place in the reflecting surface from exposure, dampness, and especially salt. Since hydrographic sextants must be used at sea in all conditions of weather, they are constantly exposed to salt spray, particularly those used in launch and small-boat hydrography. After use the entire sextant and particularly the mirrors should be carefully dried and cleaned. But the spray that finds its way around the edges of the mirror cannot be easily removed and thus is in a position to attack the mirrored coating.

A British manufacturer has recently devised round glass mirrors hermetically sealed in frames to prevent the possibility of spray reaching the mirrored surface. These mirrors are silvered, copper plated, and painted with special resistant paint and are then mounted in such a way that neither air

nor spray can possibly have access to the reflecting surface to cause deterioration. The mirrors are circular in shape to facilitate the use of the special frame required to obtain the hermetic seal.

*b. Stellite mirrors.*—Stellite is a trade name for an alloy of chromium, cobalt, and tungsten. It takes a high polish, is very hard, and does not tarnish. Stellite mirrors, which have been used in hydrographic sextants under the worst possible conditions for 10 years or more, show little or no loss in reflectivity.

Stellite mirrors have the advantage of a front reflecting surface, the error from nonparallelism of the two surfaces, of course, being eliminated. The reflecting surface must be polished optically flat throughout and be free from all scratches, cracks, blow holes, pin holes, or other defects.

Stellite mirrors should be used in all hydrographic sextants used in launches and small boats and in sextants used on board ship for hydrography. Occasionally the higher reflectivity of the best glass mirrors may be advantageous for use in difficult observations.

### *4515. Sextant Errors*

The principal errors which arise in angular measurements by sextant may be divided into two general classes: (1) those due to defects of construction or adjustment by the manufacturer, which cannot be remedied by the observer, and (2) those caused by temporary maladjustments which can and should be corrected by the user.

Errors of the first class result from one or more of the following causes:

(*a*) The graduated arc or limb is not a plane, or its graduations or those of the vernier are not accurately cut.

(*b*) The pivot of rotation of the index arm is not coincident with the center of curvature of the graduated arc, or not perpendicular to the plane of the instrument.

(*c*) The surfaces of the mirrors are not within 2 seconds of parallelism, or the surfaces of the shade glasses are not within 5 seconds of parallelism.

(*d*) The line of sight, or the axis of the telescope, is not parallel to the plane of the graduated arc.

Errors of the second class result from one or more of the following conditions:

(*e*) The index mirror is not perpendicular to the plane of the instrument.

(*f*) The horizon mirror is not perpendicular to the plane of the instrument.

(*g*) The horizon mirror is not parallel to the index mirror when the index arm is set at the zero of the graduated arc.

No correction can be made by the user to remedy the faults of inaccurate graduation or eccentricity, (*a*) and (*b*) above, although their amounts may be determined by a careful calibration (see **4518**), after which an allowance may be made for them. All navigating sextants now acquired by the Coast and Geodetic Survey are tested for these two errors at the United States Naval Observatory. Navigating sextants acquired in the past may or may not have been so tested. If they have been tested either by the manufacturer or at the Naval Observatory, a table of corrections will be found pasted on the inside of the top of the wooden carrying case.

Hydrographic sextants are not tested for these errors at the Naval Observatory.

The prismatic error (*c*) cannot occur in stellite mirrors. Glass mirrors in which this defect is found should be discarded from use and returned to the Washington Office. The shade glasses on a navigating sextant to be used for astronomic sights should be tested before use. Each shade glass should be tested separately by comparing an observation made without the shade glass with one made through it. If a combination of shade glasses is likely to be used, each of these combinations should be tested separately. No means of adjustment is provided and, when measurable errors of this nature are discovered, the shade glass in error should be removed from the sextant and returned to the Washington Office with a report of its defect.

No adjustment is provided for the binocular telescope now attached to sextants used by the Coast and Geodetic Survey (see (*d*) above). The telescope is installed by the manufacturer or by the Instrument Division of the Bureau so that its line of sight is parallel to the arc. Older navigating sextants, to which binocular telescopes have not been affixed, may be provided with an adjustment by which the line of collimation can be corrected. The method to be used is described on page 123 of Bowditch or in any good treatise on the use of the sextant.

Owing to the construction of the sextant there is a small error in small angles, due to the fact that the vertex of the measured angle is actually back of the eye. It is important only when distances are to be derived from small sextant angles, as in the sextometer method, or perhaps in small vertical or depression angles. The effect and amount of this error are considered in **2382**.

### *4516. Sextant Adjustments*

The horizon and index mirrors must be adjusted by the movements provided to the holding frames to eliminate errors (*e*), (*f*), and (*g*) in **4515**.

Referring to figure 76, the index mirror *A* must first be made perpendicular to the plane of the instrument. To make this adjustment set the index arm near the middle of the graduated arc and hold the sextant with the eye close to the index mirror and as nearly as practicable in the plane of the sextant, with the graduated arc away from the eye. Observe the graduated arc direct and its reflection in the index mirror, moving the arc slowly back and forth, and see whether the arc and its reflection appear to form an apparently continuous unbroken arc. If so, the mirror is perpendicular to the plane of the arc; otherwise, correct its position by adjusting the screw at the back of the frame until it is perpendicular.

The horizon mirror *B* should now be adjusted perpendicular to the plane of the sextant. With the index mirror in adjustment, set the index arm near zero and hold the sextant so its plane is vertical and sight at the sea horizon. Bring the horizon as seen direct and its image in the horizon mirror into coincidence by moving the tangent screw. Incline the sextant so that its plane makes a slight angle with the horizon and see if the horizon and its image are still in coincidence. If not, adjust the position of the horizon mirror by means of the screws attached at the back of the frame until coincidence is obtained.

This adjustment of the horizon mirror may be made at night by pointing the sextant at a star and moving the index arm so that the reflected image of the star appears to pass the star as seen direct. If they are not in coincidence in passing, the horizon glass needs to be adjusted as described above until one image passes directly in front of the other when tested.

The index error (*g*) in **4515** and its adjustment are considered in **4517**.

### *4517. Index Error*

The index error of a sextant is due to the fact that the reflecting surfaces of the two mirrors are not parallel with each other when the index arm is set at zero. The adjustments described in **4516** having been previously made, set the index arm exactly at zero and point the sextant at some distant object, usually the sea horizon, and rotate the horizon mirror by means of the adjusting screw (*N* in fig. 77) to one side of its frame until the direct and reflected images are in coincidence. This adjustment

may be made while viewing any distant object, terrestrial or celestial, through the sextant.

After the index error has been corrected, the second adjustment—the perpendicularity of the horizon glass—should again be verified, since its adjustment is often disturbed during the last operation.

The adjustment for index error is not essential since its amount may be determined and applied as a correction to all angles observed. But in hydrographic surveying this would be a nuisance. For limited use, when very small angles are involved as in sextometer distances, readings may be taken both *on* and *off* the arc and the two meaned. The result will be free of any index error.

For astronomic observations and the measurement of other sextant angles where utmost precision is required, the same adjustments are necessary. In addition, the exact index error should be determined at each set of observations for application as a correction to the observed angles.

The amount of the index error may be determined by one of the following three methods:

(*a*) With the sextant held vertically and pointed at the sea horizon bring the direct and reflected images into coincidence and read the setting of the index arm. Repeat several times, bringing the reflected horizon down to coincidence and up to coincidence alternately, taking a mean of the results. If the zero of the vernier is to the right of the zero of the arc, or *off the arc*, the correction is positive and should be added to measured angles. If it is to the left, or *on the arc*, the correction is negative and should be subtracted from the measured angles.

(*b*) Substitute a star at night for the sea horizon, point the sextant at the star and bring the direct and reflected images into coincidence and read the setting of the index arm. Repeat several times and use a mean of the results as above.

(*c*) Measure the apparent diameter of the sun with the sextant held vertically, bringing the upper limb of the reflected image to touch the lower limb of the direct image. Read the angle. Then bring the lower limb of the reflected image to touch the upper limb of the direct image and read the setting *off the arc*. Half of the difference of the two readings is the index correction, positive or negative as the larger of the two values is off or on the arc, respectively. For example, if the diameter measures 33′ 50″ on the arc and 32′ 40″ off the arc, the index correction would be ½ (33′ 50″—32′ 40″) = 35″(minus). Several such observations should be taken and the mean used. The accuracy of the result may be verified by comparing the sun's semidiameter for the date of observation as taken from the Nautical Almanac with one-quarter of the sum of the two readings irrespective of sign.

The adjustments of all sextants used in hydrographic surveying should be verified, and readjustments made if necessary, each morning before the start of the day's work. They must be verified each night at the close of the day's work. The fact that this has been done at both times and the amount of the index correction found at the end of the day, if any, must be entered in the Sounding Record.

### *4518. Sextant Calibration*

The error due to eccentricity and inaccurate graduation is a constant for any one angle. These are the errors that are determined by test at the United States Naval Observatory. A sextant for which these values are not available can be tested in the field by comparing angular values determined by triangulation or measured with a theodolite, with sextant measurements. In an area where there are numerous triangulation stations the sextant to be calibrated may be placed on a leveled planetable at one of the triangulation stations and the angles between other surrounding triangulation stations carefully measured.

Angles may be measured with a theodolite for this purpose and subsequently measured by sextant from the same position. Angles of as many different sizes as practicable should be measured, preferably angles approximating 10°, 20°, 30°, 40°, etc. Assuming that the angles measured by theodolite are correct, the differences are the sextant errors due to eccentricity and graduation. From these errors a table or curve may be constructed from which the error for any angle may be found by interpolation.

Errors of graduation may also be detected by placing the zero of the vernier in exact coincidence with selected graduations of the arc and observing whether the last numbered division of the vernier also coincides with a division of the arc. This test should be made at numerous positions of the graduated arc, and the agreement should be perfect in every case.

## 452. Sextant Angles

### *4521. Horizontal Angles*

To measure the angle between two terrestrial objects in a horizontal plane the sextant is held horizontally, handle down, with the telescope pointed toward the left-hand object. This object is viewed directly over the top of the horizon mirror, while the index arm is moved until the image of the right-hand object is seen, by double reflection, in the horizon mirror directly below. With both objects in view, and in approximate coincidence, the index arm is clamped and the objects are brought into exact coincidence by means of the tangent screw.

This measurement of horizontal angles is the basis of fixing the position of the survey vessel by the three-point problem in hydrographic surveying.

Little experience is required to measure unchanging angles between prominent objects where the sextant is mounted on a steady base or even where held in the hand by an observer on land. In hydrographic surveying, however, the angles to be measured are always changing more or less, the survey vessel is frequently far from steady, and the objects are often small or faint. Considerable practice is required to enable one to observe sextant angles quickly and accurately under these conditions.

Where the objects are prominent and readily visible, and especially when the angle is changing rapidly or the survey vessel is unsteady, many observers prefer to use the sextant without its telescope because of the larger field of view.

Where the objects are distant, indistinct, or indefinite, when the angles are changing slowly, and particularly where a small error in the angle will affect the position considerably, a telescope should always be used.

When the angle to be observed is changing appreciably, the usual procedure is to bring the object seen direct and the reflected image into approximate coincidence and maintain them so by moving the free index arm until it is about time to *mark* the angle. Just before the *mark* the arm is clamped and the two objects are brought into and maintained in exact coincidence by the use of the tangent screw until the word *mark*. When the angle is changing rapidly the tangent screw cannot be moved fast enough for this, but in this case so much accuracy is unnecessary. For such angles many observers set the clamping screw partly, so that there is a little friction when the index arm is moved, the angle being taken without using the tangent screw. The magnifying glass should be adjusted beforehand and no part of the arm should be touched after *marking*, neither should the sextant be set down, until after the value of the observed angle has been read. This requires care, but is generally preferable to clamping the arm after

*marking* the angle, because clamping the setscrew often causes the arm to jump a little, introducing an error in the reading.

As a general rule, after taking an angle and reading it, an observer should not move the index arm until the position has been plotted, so that he can verify the reading if necessary. In any event it is good practice, after an angle has been observed and read, to verify the reading of the sextant before the arm is moved. If the sextant is required immediately to measure a cut or another angle, the reading should be verified at once.

When the survey vessel is rolling and pitching considerably the greatest knack is required to measure sextant angles accurately and at the required instant. The sextant must be held in a horizontal plane for both the direct and reflected objects to be visible and for the resulting angle to be correct. Under these conditions the observer should station himself where the movement of the vessel is at a minimum and should learn to counteract this movement by an opposite movement of the sextant so that it will always remain as nearly in a horizontal plane as practicable.

### 4522. *Angles to Faint Objects*

Where the objects or signals are faint or where angles are being measured between survey buoys out of sight of land, the difficulties encountered may be extremely discouraging to a beginner. The greatest difficulty is usually in reflecting the right-hand object, which sometimes cannot be found in the sextant even though it can be seen fairly well when observed directly. In such cases it is of material assistance to set the sextant in advance close enough to the expected angle so that the reflected image of the right-hand object will be within the field of view of the telescope.

There are several methods of finding approximate angles:

(*a*) The angle may be scaled from the boat sheet with a protractor set at the approximate location of the next position to be fixed.

(*b*) If the angle is not changing too rapidly the rate of change between the two preceding angles may be applied to determine the approximate angle at the next position.

(*c*) The relation between the faint signal and a conspicuous object or peculiar cloud formation on the skyline near the signal may be noted, and the conspicuous object or cloud formation reflected first, from which a slight movement of the sextant will bring the signal within the field of view.

(*d*) With the sextant set approximately at zero the right-hand object may be observed direct and then found in the index mirror. By slowly moving the index arm and at the same time rotating the sextant to the left, the image of the right-hand object may be kept in view in the index mirror until the left-hand object is seen directly above it.

(*e*) Every observer should determine the angle subtended between the ends of the thumb and little finger of one hand outstretched at arm's length, so that by sighting over his hand and moving it along the horizon he can step off an approximate angle between any two objects.

If the middle object of a three-point fix is difficult to reflect, the observers may measure the right angle and the sum angle between the right and left objects, subtracting the former from the latter to obtain the left angle.

If the right-hand object is difficult to reflect but the left-hand one is very distinct, the sextant may be held upside down to look directly at the right-hand object and reflect the left-hand one. This is an unnatural and inconvenient procedure but may have to be resorted to occasionally.

Inexperienced observers have great difficulty in measuring angles between survey buoys out of sight of land, particularly when the heading of the survey vessel is changed frequently or by a large amount. The buoys are frequently so distant that they can

be seen only through the telescope and, because the horizon is devoid of reference points, there is great difficulty in finding even the direct object unless it is watched constantly. In survey operations of this nature, while the same or approximately the same course is followed, it is advantageous to note the bearing of the direct object with reference to some part of the ship's bridge or by pelorus, if necessary. When frequent or large changes in course are made, the only recourse is to note the approximate bearing of the direct object by compass. If the direct object can be maintained in view or found when desired, the reflected object may be found by noting the rate of change of the angle, or by bringing the two objects together in the sextant a sufficient number of times between positions to keep the angle always approximately on.

In using any of the above methods for picking up faint objects, observers, and especially beginners, are warned against getting an approximate angle and letting their imaginations do the rest. Such methods can, of course, be used only to aid in getting the objects within the field of view. If one of the objects cannot actually be seen or if they are not in coincidence at the *mark*, the angle must be reported to the officer-in-charge as a *miss*.

### *4523. The Measurement of Large Angles*

Angles greater than 145° or 150° cannot be measured with the ordinary sextant. Occasionally in hydrographic surveying such angles must be measured. This is sometimes done by *splitting* the angle between two observers. To do this it is essential that there be a well-defined object somewhere near the horizon to serve as a middle object to which the two parts of the sum angle may be observed. In three-point fix hydrography where the control stations are buoys out of sight of land it is sometimes practicable, especially in the tropics, to use well-defined points of cloud formations near the horizon for this purpose.

A sextant has been designed in Europe embodying a prism in such a way that angles up to 180° can be read on it. This sextant has not been used by the Coast and Geodetic survey.

### *4524. Vertical Sextant Angles*

The sextant was designed primarily for use at sea by mariners in observing the altitudes of celestial bodies and it is also used for this purpose by hydrographic surveyors. To make such an observation the instrument is held so that its plane is vertical, with the telescope directed toward the horizon. Observing the horizon in direct view, the index arm is moved along the arc until the image of the celestial object is seen reflected in the horizon mirror. When both the celestial object and the horizon are seen in the telescope, the arm is clamped and by means of the tangent screw an exact coincidence is obtained when the plane of the sextant is truly vertical.

The principal difficulty in measuring such an angle is that it must be *marked* so as to measure the angle in a vertical plane. To ensure this, the observer must swing the instrument slightly to the right and left of the vertical. The reflected object will appear to describe the arc of a circle, the lowest point of which marks the true vertical, and when coincidence is obtained at this point the angle should be *marked*. Altitudes of celestial bodies should not be measured where the sextant is pointed through the rigging or where other nonvertical parts of the vessel are in view to distort the observer's sense of perpendicularity.

When celestial bodies that have an appreciable diameter are observed, one of the limbs, usually the lower, is brought into coincidence with the horizon, the observed angle being corrected for the semidiameter of the body.

For observations of the sun, shade glasses are nearly always required to reduce the intensity of the sun's rays and under certain conditions may also be required to diminish the glare of the horizon. The errors which may be introduced through the use of imperfect shade glasses are described in **4515**.

There is no difficulty in *finding* the reflected image of the sun in a sextant. Because of its brightness, its reflected image is usually easily brought into view in the horizon mirror by pointing the sextant at the horizon in the general direction of the sun and moving the index arm until the reflected sky begins to appear brighter, after which the sun's image may soon be found. When a star or planet is to be observed there is greater difficulty in bringing the reflected image into view. Sometimes this may be done by the same method used for the sun, but if this method is used, the pattern of stars in the vicinity of the one selected must be compared with those seen in the mirror in order to ensure that the observation is being made on the selected star.

When the star cannot be found by the above method, there are several other methods of *finding* it and bringing it into approximate coincidence with the horizon:

(*a*) With the index arm set approximately at zero the telescope may be pointed directly at the star, when both the direct and reflected images of the star should be visible. Holding the sextant steady and always keeping the reflected image of the star in the horizon mirror, the index arm is moved slowly along the arc at the same time moving the sextant slowly in a vertical plane until the star is *brought down* to the horizon.

(*b*) The horizon may be *brought up* to the star by holding the sextant, set approximately at zero, in an inverted position with the telescope pointed at the star. With the star maintained in direct view the index arm is moved until the reflected image of the horizon is in approximate coincidence. This is a somewhat awkward procedure since the sextant must be held in the left hand, for which it was not constructed, and care must be taken to avoid intercepting the line of sight with the right hand, which is moving the index arm. After approximate coincidence has been obtained, the position of the sextant is changed to normal for the actual observation.

(*c*) The approximate altitude of a celestial body may be determined for any given instant and position on the earth by calculation, from tables, or graphically (see **3387**B). Once this approximate altitude is known, it may be set on the sextant and should be close enough to the actual altitude so that the selected body will appear in the reflected field of view when the telescope is pointed in the proper direction at the horizon below. A slight rotation of the sextant to the right or left of where it is first pointed is sometimes necessary to bring the star or planet into view.

In all altitude measurements of celestial bodies the telescope must be accurately focused to the end that both the horizon and the celestial object or its limb appear as sharp and definite as possible. Only then will accurate observations result.

### *4525. Sextant Angles at Night*

When altitudes of celestial bodies are measured at night, provision should be made to illuminate the arc of the sextant while it is being read. If ordinary illumination is used the sudden brightness of the light contracts the pupil of the observer's eye to interfere with the observations.

Some sextants are specially equipped for this purpose with a small electric bulb, carried on the index arm, located in a position to illuminate the arc. The bulb is lighted from a small battery concealed within the handle. A sextant not so equipped can be altered on shipboard for this purpose. The wooden handle should be removed and replaced by one of larger cross section within which one or two longitudinal holes are

bored to hold the battery or batteries. Small "pen" batteries approximately 2 inches long by ½ inch in diameter should be used.

On a vessel not provided with sextants equipped for night observations, or if the number of such observations to be made does not warrant alteration of the sextants, they should be read by illumination provided from a flashlight held by an assistant. The flashlight must be held against the graduated arc but to one side of the vernier to illuminate it diagonally, so as not to interfere with its being read.

#### *4526. Inclined Sextant Angles*

The sextant is used to determine the azimuth between two buoys or other objects by the measurement of an inclined angle between that line of sight and a celestial object, generally the sun. To measure such angles the sextant is held at an inclination to the horizon. This is the most difficult type of angle to measure with a sextant, because it has to be held at an unnatural angle with the horizon, this angle differing with almost every measurement. The principal difficulty is in bringing the sun into approximate coincidence with the objects on range. Frequently the method described in **4524**(*a*) for bringing a star down to the horizon has to be used. After approximate coincidence has once been obtained the final observation is no more difficult than any other.

A vertical angle must be observed simultaneously with the inclined angle by a second observer. The inclined angle may be reduced to a horizontal angle by one of the formulas given in **3338**.

In measuring inclined angles for sun azimuths, when the sun must be observed direct and the buoys on range reflected, the intense rays of the sun make the reflected buoy difficult or impossible to see. An improvised shade may be used to advantage to prevent the rays of the sun from passing around the shade glass and into the telescope. Any stiff piece of cardboard or other material may be used, in which a circular hole the size of the shade glass is cut, and through which the direct object may be observed. This is temporarily attached to the sextant. A size 6 inches square will suffice, with a horizontal piece cut out of its right edge, through which the ray from the reflected object passes, and with slots cut in its lower edge by which it may be temporarily fastened to the frame of the sextant. A simpler and smaller card containing the same circular and horizontal openings may be made to rest on top of the frame of the sextant and be temporarily attached with Scotch tape to the frame of the shade glass.

### 453. PROTRACTORS

The protractor in its simplest form is an arc or circle of flat material, graduated in degrees, with which angles may be plotted or scaled on a plane surface. In hydrographic surveying the type most widely used is the three-arm protractor of metal or transparent material. Horizontal angles, usually forming three-point fixes, are plotted graphically with the three-arm type.

#### *4531. Metal Three-Arm Protractor*

The metal three-arm protractor (fig. 78) consists essentially of a graduated circle with one fixed arm and two movable arms pivoted at its center so that the extension of each fiducial edge always passes through the precise center of the graduated circle. The arms are about 18 inches long. The circle is usually about 6 inches in diameter,

graduated to half-degrees, with a vernier on each movable arm which permits a setting to the nearest minute. The graduations of the circle should be accurate to within one-half minute, and the arms should be truly radial also within one-half minute.

The center arm of the protractor is fixed at the zero of the scale. Each movable arm has a vernier, setscrew, and tangent screw. The graduations of the circle are marked with two sets of numbers so that angles may be read either clockwise or counter-clockwise from the zero of the scale. The construction of the protractor permits setting a small angle approaching 0° on one arm only, the minimum angle which can be set on the other arm being about 12°. In order to plot all three-point fixes two metal protractors are required, one constructed to accommodate a small right angle and the other to accommodate a small left angle.

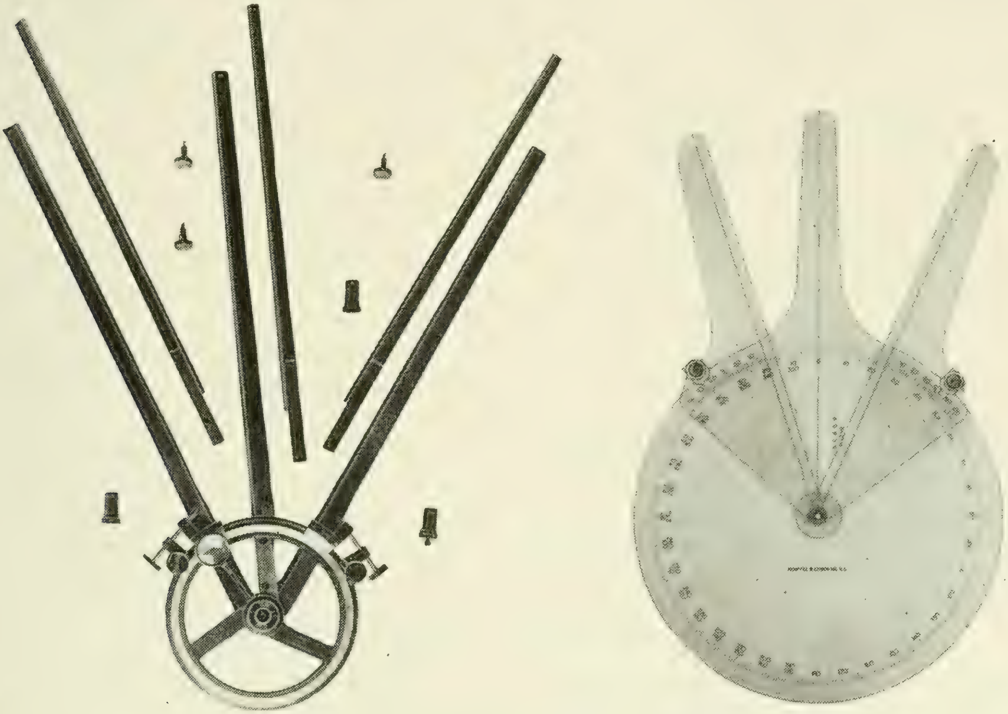

FIGURE 78.—Metal three-arm protractor with attachments, and celluloid protractor.

At the center of the graduated circle is an open metal socket into which may be fitted any one of several interchangeable centerpieces. One of these centerpieces has a pricker which is held above the paper by a small spring until the plotter is ready to mark his position. When the pricker is depressed by hand, a small hole is made in the paper, a shoulder preventing the pricking point from being pushed into the paper more than just enough to mark the position. A second centerpiece is provided with a transparent bottom on which are etched two perpendicular crosslines which mark the center of the graduated circle. This centerpiece is used in setting the protractor on any previously plotted position. A third centerpiece has a small round opening through which a plotted position may be marked by pencil.

A magnifying glass of low power is attached to the instrument so that it can be rotated around the center, in order to facilitate reading the graduated circle.

*Extension arms.*—A removable extension, about 15 inches long, is provided for each of the three arms. These extensions are not interchangeable, each extension fitting only its corresponding arm. When in place they form true, straightedge extensions of the arms of the protractor. Setscrews are provided for fixing them in place.

For plotting angles on stations at great distances, metal protractors have sometimes been fitted with a second set of extension arms to be attached to the first set. It is difficult to provide sufficient rigidity for these extensions, and their use is not recommended, especially since extremely small angles, which usually occur in observations on distant signals, require very accurate plotting.

To overcome the lack of rigidity, braces in the form of metal arcs with central slots have been devised for attachment to the arms at the points where the extension arms are fastened. These braces can be used only for comparatively small angles. After the extension arms have been added, the brace is placed in position and the setscrews are screwed down through the slot in the brace and into both arms. When these are used at least one setscrew in each brace must be loosened each time a new angle is set on the protractor. After the brace has been locked, the setscrew on the vernier should be released and the angle verified before the position is plotted.

### *4532. Adaptation for Wire-Drag Plotting*

Wire-drag plotting is facilitated by a simple adaptation of the metal three-arm protractor. In the base of the transparent centerpiece which contains crosslines and a center hole, a small eccentric hole is drilled at a distance from the center corresponding to the length of the towline at the plotting scale. A special pointer is mounted on top of the centerpiece in such a way that the pointer is in line with the two holes, the end of the pointer reaching to the graduated arc of the protractor.

In a wire-drag survey the three-point fix is plotted in the usual manner, the center of the protractor indicating the position of the guide launch. The buoy angles are then set with the new device; the position of the near buoy is plotted through the eccentric hole, and a short direction is indicated to the distant buoy. Different towline lengths or smooth sheets of different scale will require different centerpieces.

### *4533. Test and Adjustment of Three-Arm Protractor*

Protractors, when first purchased or when repaired at the Washington Office, are verified for accuracy before being issued for use. But since both metal and transparent protractors are subjected to exposure and hard use in the field, they must be frequently verified during use. An endless amount of trouble will result from the use of inaccurate protractors.

An aluminum plate with accurate angles of 90° on each side of the center may be requisitioned from the Washington Office for use in testing protractors. If the construction of such a plate is undertaken in the field, it should be made with extreme accuracy on metal or on metal-mounted paper.

In testing a protractor the centerpiece with the transparent bottom and crosslines should be used. The bottom of the centerpiece should be flush or nearly flush with the hub of the protractor to avoid parallax. The centerpiece should be tested for concentricity by placing the intersection of the crosslines above a marked point on a sheet of paper and rotating the centerpiece in the socket. If the intersection of the crosslines coincides throughout the rotation with the marked point, the centerpiece may be assumed to be correct. The other centerpieces should also be checked. The

pricker centerpiece may be tested in a similar manner by pricking several points in the paper with it in various positions. The prick points should coincide in one hole.

Each arm of a protractor should be tested for straightness against a straightedge. It may also be tested by drawing a fine line along the fiducial edge of the arm with a chisel-edged pencil, and then reversing the arm to the opposite side of the line; if the fiducial edge still coincides with the pencil line, the arm may be assumed to be straight. If the extensions to the arms are to be used, this test should be made for the entire length of the arm with the extension locked in place.

After the arms and centerpieces have been tested, the protractor should be placed on the aluminum plate and centered precisely at the intersection of the two lines at right angles. The fixed arm should be moved to coincide with the central line, and the right and left arms moved to coincide with the lines at 90° to the central line. The two movable arms should be clamped in these positions with their arms coinciding precisely with the lines. If the angles read exactly 90°, the verniers are correctly set with reference to the graduations at these points. If they do not read exactly 90°, the verniers should be adjusted by loosening the screws which hold them and moving them so that they will read precisely 90°. The verniers are then locked firmly in position by tightening the screws. The adjustment should be checked.

When the two movable arms are set 90° to the right and left respectively of the fixed arm, a line drawn along the fiducial edge of one of these arms should be a straight-line extension of a line drawn along the fiducial edge of the other. Likewise, each arm when set at 180° should form a straight-line extension of the fixed arm.

Metal protractors should be tested at the beginning of a field season, before plotting a smooth sheet, and at least once a month during their use.

### *4534. Use of Three-Arm Protractor*

The three-arm protractor is used almost constantly in hydrographic surveying. With it three-point fixes may be readily plotted, as well as angles from a known position.

To plot a three-point fix (see **333**), the left movable arm is turned away from the fixed arm by the amount of the left angle, the arm is clamped in place and the final setting made with the tangent screw and vernier. The procedure is repeated for the right angle. After the angles have been set the instrument should be grasped by the metal circle and the fixed arm, and centered at the estimated position of the fix. With the fingers of one hand used as a guide to keep the fixed arm bisecting the center station, the protractor is moved toward or away from the stations until each arm bisects its respective station. During this operation speed may be gained by keeping the side arms at approximately equal distances from the respective stations. A prick mark or pencil mark is then made at the center of the protractor, the position thus marked representing the location of the observers at the time the angles were taken.

In using a metal protractor it will occasionally be found that one or more of the plotted control stations are obscured by the metal circle. To overcome this difficulty a protractor of transparent material may be used.

To plot an angle from a known position, the instrument is centered accurately over the position by means of a transparent centerpiece, the fixed arm is rotated until it passes through the plotted position of the initial object, and the right or left movable arm is set at the desired angle. The cuts may then be drawn along the fiducial edge of the arm with a chisel-edged pencil. Before each cut is drawn, the position of the pro-

tractor should be checked to see that it is properly centered over the known position and that the fixed arm passes through the initial point.

In plotting hydrography accuracy should be the objective of the beginner. Speed will be gained with experience.

### *4535. Care of Three-Arm Protractor*

The metal three-arm protractor is an accurate and expensive instrument and requires as much care to preserve its initial accuracy as does any delicate survey instrument. Each protractor should be stored in its own wooden box when the day's work has been completed, and a visual check should be made to ensure that each accessory is in its proper compartment in the box.

During use, especially during rough weather, provision must be made to eliminate any possibility of the protractor's slipping off the plotting table. Ingenuity will suggest several methods of securing the instrument on the table when not in actual use. The arms and the extension arms of metal protractors are straightedges which may be easily bent if the protractor is dropped or carelessly handled. After any accident to the instrument the straightness of the arms should be carefully verified before subsequent use.

If a metal protractor is exposed to salt spray or happens to be immersed in salt water, it should be cleaned and oiled immediately in accordance with the instructions given in **4313**.

### *4536. Celluloid Protractors*

The transparent protractor (fig. 78) in most general use is constructed of celluloid, with a solid disk about 12 inches in diameter containing a circle graduated in degrees, and one fixed and two movable arms also of celluloid extending about 13½ inches beyond the edge of the disk, each containing an etched line radial with the center of the protractor and which serves as the plotting edge. Each of the movable arms contains a vernier graduated in 2-minute intervals. Angles can be set or read to the nearest minute. A setscrew on each movable arm clamps the arm to the solid circle near its outer rim, and each arm may be set and clamped in place independently of the other.

Although limited in accuracy the celluloid protractor has several advantages over the metal protractor. Its transparency makes it possible to see the plotting sheet and the stations thereon. Positions may be plotted quite close to the plotted positions of the control stations. The protractor is lighter in weight, more easiy read, and consequently can be set more quickly than the metal protractor. It is easily cleaned and contains practically no metal to stain the sheet. The solid celluloid disk serves to protect the sheet from being soiled by the hands of the plotter.

A celluloid protractor may be used whenever desired for boat-sheet plotting, but its use for smooth-sheet plotting is restricted by the limitations in **7622**.

The celluloid protractor is most useful in launch hydrography, where the positions are usually comparatively near the control stations and rapid plotting is necessary, especially where there are currents. Compared to the metal protractor, it can be more easily held in place when the launch is pitching and can be set more readily regardless of vibration from the launch motor. It is less likely to be damaged if thrown off the table by the violent motion of the launch in a rough sea.

*Test for accuracy.*—Celluloid protractors cannot be adjusted. They should, however, be tested on the aluminum plate in order to determine whether the scribed lines

on the arms are straight and whether there are any errors greater than 2 minutes in the graduations.

*Method of use.*—The celluloid protractor is used in a manner similar to that described for the metal protractor, except that there are no vernier tangent screws.

Where one or more stations on a boat sheet are just beyond reach of the arms of a celluloid protractor, a system of lines 3 or 4 inches long can be drawn radiating from each station. By the use of these, an arm can be pointed toward a station beyond its end.

*Care.*—Celluloid protractors are constructed from a perishable material and reasonable care must be taken to prevent their deterioration. Continued exposure to the sun gradually renders them opaque and may distort the material so that the graduations are no longer accurate.

The instrument is furnished in a leatherette-covered cardboard folder, and when not in use should be kept in this folder. Celluloid protractors should never be stored touching or in close proximity to steel or felt. A chemical reaction occurs between these two materials and the material of which the protractor is made.

The celluloid protractor, being of light material, may be easily blown overboard if used in an exposed place. This possibility should be guarded against by securing the protractor to the edge of the plotting table with a twine or tape lanyard of sufficient length to permit use of the protractor on the sheet.

### *4537. The Odessey R.A.R. Protractor*

Where distance circles at regular intervals are drawn on R.A.R. hydrographic sheets, a series of concentric circles drawn on celluloid can be used advantageously to plot the residual distances between the distance circles and, under certain conditions, to plot the positions themselves.

The device must be constructed for the scale of the sheet and the interval between distance circles. It is simply a series of closely spaced concentric circles drawn to represent distances from the center in terms of meters or time intervals, whichever are used. Circles should be drawn so that those of the same unit interval are readily distinguishable. The following scheme has been found satisfactory for a 1: 80,000 scale using time intervals: A circle for each 0.05 second of time; those representing seconds—in heavy solid lines; those for half-seconds—in heavy pecked lines; those for tenth-seconds—in fine solid lines; and those for 0.05 seconds—in fine broken lines.

A similar scheme can be adopted for other scales and for distances in meters.

The diameter of the outer circle on the device must be at least equal to, and preferably double, the interval between distance circles on the sheet. The system of concentric circles is either drawn or reproduced photographically on clear celluloid of low distortion. The lines must not be so heavy as to decrease appreciably the transparency of the celluloid.

In plotting R.A.R. distances, the device is placed on the sheet so that its center marks the increment or decrement from the nearest distance circle on the sheet, the partial distance being measured by the closely spaced concentric circles. The interpolated concentric circle on the device will be tangent to the distance circle on the sheet. The center of the device then marks the correct distance, assuming there is no distortion in either sheet or device and that the circles on both are accurately constructed. If the diameter of the largest concentric circle on the device is double the interval between distance circles on the sheet, the device may be used to compensate for the distortion of a hydrographic sheet between distance circles.

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Where a position is fixed by only two R.A.R. distances, the device may be used for plotting the position directly. After it has been placed, as described above, so that its center correctly marks one distance, it can be moved until its center correctly marks a second distance referred to another set of distance circles drawn about a second R.A.R. station, while keeping it in its correct relationship to the first distance circle. The center of the device will then mark the position fixed by the two R.A.R. distances. (See **7631***a*.)

### *4538. Metal R.A.R. Protractor*

A metal plotting device has been designed which can be used to advantage under certain conditions to plot R.A.R. positions. The device consists of three arms pivoted at a pricking device. With zero at the pivot, the arms are graduated to represent distances (in meters or seconds of travel time) at the scale of the hydrographic sheet.

Three index heads, or disks, are provided. These are fastened over the sheet, one at each R.A.R. station, the index being vertically above the plotted position of the station. The arms slide in grooves in rotatable inner parts of these heads. The index is provided with a vernier and the head with a setscrew to clamp the arm at its correct setting.

If distances are determined to two R.A.R. stations and the distances are set on the arms passing through the respective stations, the pricker at the pivot will move mechanically to the position where the bomb was fired. Owing to inherent small errors and distortions of the plotting sheet, the three arms cannot be used simultaneously, but the two which give the strongest intersection or the most consistent results can be used, with a third distance used as a check. Or the position can be plotted with each pair of distances and the three resulting positions compared.

The instrument must be graduated for a mean velocity of sound or for a selected plotting velocity, as 1,460 meters per second, the plotting velocity used on all R.A.R. smooth sheets (see **763**). In the latter case each R.A.R. distance must be corrected arithmetically to the plotting velocity before being used, and in the former case similar corrections can be made when the actual velocity differs enough from the velocity of graduation to warrant it. Corrections for distortion of the plotting sheet can be made in the same manner.

The instrument must be graduated for one scale of hydrographic sheet, although it can be used for other scales by applying a factor to the distances before plotting. Where the scales involved are double one another this is simple.

### *4539. Special Types of Protractors*

Several forms of special transparent protractors, of advantage in particular circumstances, have been prepared in the Washington Office. A protractor printed on tracing paper, merely a graduated circle 3⅝ inches in diameter with a marked center, is available. This is particulary useful for plotting positions so close to the stations that one or more of them are obscured by either the metal or transparent three-arm protractors. For use in plotting, continuous lines are drawn from the center of the protractor to represent the angles measured, after which the protractor is used in the same manner as is the three-arm protractor. If other sizes are needed to meet special conditions they will be furnished on request.

Another form of protractor available at the Washington Office consists of a circular piece of celluloid, similar in size and appearance to the solid part of the celluloid three-arm protractor, throughout which numerous parallel lines have been printed

paralleling the 0°–180° line of the protractor. This protractor is especially useful in plotting bearings or azimuths on a smooth sheet or boat sheet, since the protractor can be centered over the point from which the bearing was measured and oriented by means of the grid of parallel lines.

Several refinements to the standard metal three-arm protractor have been devised in recent years. These, however, are not in use in the Coast and Geodetic Survey. The British have developed a metal protractor with micrometers substituted for the verniers, and release clamps substituted for the setscrews, on the movable arms. It is claimed for this instrument that the angles can be set more rapidly and with greater ease to single minutes with the unaided eye. No magnifying glass is provided. The micrometer is thrown in or out of gear by clamps which are released by the simple grasp of the thumb and finger. After an approximate setting of the angle, the act of releasing the grip clamps the arm, and the final setting is made by the micrometer tangent screw.

Another European development of the metal protractor elevates the protractor about 2 inches above the plotting sheet. Accessories to this development are station holders or guides, one of which can be placed over each station to guide the arm automatically. These guides are of practical value only where a large number of positions are to be plotted from the same three stations. Each station holder is so constructed that when set in place over the plotted position of a station, rollers guide the fiducial edge of the arm through the plotted position of the station as the instrument is moved with the arms unclamped. When the center of the protractor is moved into approximate position, the roller guides force the movable arms to settings approximating the observed angles; then as the observed angles are accurately set by tangent screws, the center of the protractor automatically moves into the position to be plotted. After a position has been plotted, the movable arms are unclamped and the protractor is moved ahead to the vicinity of the next position. An advantage of the elevation of the protractor above the sheet is that it allows the draftsman to see almost all of the work on the sheet and permits a limited amount of writing on the smooth sheet without removal of the protractor.

## 454. Timepieces

Accurate time is essential in most survey operations and in navigation. Vessels and field parties of the Coast and Geodetic Survey are provided with the necessary chronometers, clocks, and stop watches for use in all operations.

### *4541. Chronometer*

Chronometers and their use on shipboard are described on pages 128 to 135 of The American Practical Navigator (Bowditch). Methods of determining their rates and errors are also described. Every hydrographer should be familiar with their use and care.

The break-circuit chronometer and the chronographs used in R.A.R. are described in **673**. Descriptive details which can be readily found elsewhere have been omitted from this Manual. The information is limited to the most important precautions in handling and use.

*a. Care.*—The case in which the chronometers are kept should be located as nearly as practicable on the centerline of the vessel and where it will be protected from shocks or jars. Chronometers should not be exposed to rapid changes of temperature and

should be removed as far as practicable from masses of vertical iron. The case should have a glass top through which to read the chronometers and should be subdivided into separate compartments, one for each chronometer. Each compartment should be padded and lined with baize cloth, so that the chronometer fits in it snugly and to reduce any jar. A chronometer should never be removed from its individual box, except in an emergency, nor should the chronometers in their boxes be removed from their padded compartments except when urgently needed elsewhere. Chronometers must never be adjusted or reset on board ship.

In transporting a chronometer by hand it should first be clamped in its gimbals and always placed in the carrying case provided for that purpose. It should be handled with the greatest care and only set down in transit on a cushion or some shock-absorbing support.

*b. Preparation for shipment.*—Before a chronometer is prepared for shipment its balance wheel must be stopped. This is done by allowing the wheel to strike against a small piece of paper until motion ceases. A stiff object or the finger must never be used for this purpose. As the balance wheel is very heavy compared to its supporting pivots, it is imperative that it be locked motionless during transit to prevent damage to the delicate pivots. The wheel is locked by inserting soft cork wedges as nearly opposite the spokes of the wheel as possible. Wedges should be pressed in carefully and simultaneously to avoid a sideways pressure on the pivots. They should never come in contact with any of the adjusting screws in the balance wheel. Wedges should be firmly inserted to ensure their remaining in place but must never be forced. Cork wedges will be issued with most chronometers, but should none be available, a soft and resilient material should be used.

A chronometer should always be removed from its gimbal rings for shipment. It should then be packed in its box, surrounded on every side and top and bottom by crushed paper so that it cannot possibly move in the box during shipment.

The chronometer box should finally be wrapped hermetically with paper to prevent infiltration of dust. In the outer shipping case it should rest on and be surrounded by crushed paper or other cushioning material. Excelsior must never be used as it is dusty and the fine powder will sift through exceedingly small openings.

*c. Winding.*—Chronometers must be wound at the same time each day, despite the fact that they are ordinarily constructed to run for 56 hours without rewinding. This regular daily winding ensures a uniform rate. To wind a chronometer, turn it gently on its side and insert the key in its hole until it seats. Steady the instrument with one hand and wind counterclockwise for 7½ turns. The last half-turn must be made slowly and gently until the stop is reached. After winding, the key is removed and the chronometer gently returned to its normal position. Where there are several chronometers, they should be wound in the same order daily, and after all have been wound the indicator of each should be inspected to ensure that each has been fully wound and that none was omitted.

*d. Comparison.*—When a survey party is engaged in operations where accurate chronometer time is needed, daily comparisons of all chronometers should be made with radio time signals. The daily comparisons should be begun far enough in advance of their need to establish an accurate rate for each chronometer.

### 4542. *Hydrographic Clocks*

In hydrographic surveying a sturdy, accurate clock by which to record the times of positions and soundings is essential. Tide reducers, the spacing of soundings between positions, the interval between soundings, and other events are all controlled by recorded time. Accurate time is most important in areas having a large range of tide, such as Alaska and New England.

To be adequate a clock must be sturdily constructed to withstand hard usage, and must be sprayproof. It should be of the 8-day type with an easily read 6-inch dial and should be enclosed in a transparent-faced, nickel-plated case, arranged for wall mounting by means of screws.

For portable use, especially in launch hydrography, it is most convenient to mount the clock on the sloping front of a box about 12 inches high with a 10-inch square base. The box should be provided with a handle for carrying. The front of the box should slope about 30° from the vertical. Such a box provides a secure base for the clock and affords it some protection. For additional security, screw eyes may be screwed into the sides of the box for use in lashing it to a bulkhead. Mounting a clock permanently on a canopy or bulkhead, or using it unmounted, is not as satisfactory as the box mounting.

Hydrographic clocks must be compared and set to correct time before the start of the day's hydrography and compared after its conclusion. When practicable, they should be checked several times a day. When coordinated survey operations take place in different parts of a ship the several clocks used for recording time must be kept within a few seconds of agreement and must be compared with one another as frequently as necessary to ensure this. (See also **6734**.)

Any hydrographic clock which cannot be adjusted to maintain correct time within 3 minutes per 24 hours should be returned to the Washington Office for repairs.

The recorded times of soundings should generally be within 1 minute of correct time, although this limitation may be exceeded for hydrographic parties based in camps in remote places without provision for accurate time comparisons.

### 4543. *Sounding Interval Clock*

A hydrographic clock that will ring a bell or buzzer at certain selected intervals of time has been designed by an officer of the Coast and Geodetic Survey. It is known as the "Green Hydrographic Clock." The mechanism consists of contacts with which the second hand makes an electric contact at intervals of 15, 20, 30, or 60 seconds. The contacts are connected to a bell or buzzer, operated by electricity furnished by dry cell batteries or by ship's current. The batteries, and also the bell and switch, if desired, can be placed inside the box described in **4542**. The box affords protection from the weather and makes the whole a compact unit. Such a clock has the obvious advantages of ensuring that the time intervals will be equal, of giving the recorder more time for his other duties, and of lessening the possibility of a missed sounding or an erroneous interval owing to the recorder's inattention to the clock.

Besides its use as a hydrographic clock, it is of value when navigating in fog. The clock can be set at the 60-second interval and the whistle blown at every buzz when in Inland Waters and at every alternate buzz when International Rules apply. Other uses will be found, whenever definite intervals of time are needed.

### *4544. Stop Watch*

A stop watch has many uses, both in navigating and surveying, and its use is essential for measuring small intervals of time accurately. It is used in current observations, in checking the speed of echo-sounding instruments, and in R.A.R. for timing the ship's run between the instant a bomb strikes the water and its explosion. In navigating and piloting it is useful in measuring wind velocity with an anemometer, in counting the revolutions per minute of the ship's propeller, in taking celestial sights, in measuring the distance from shore by an echo, and in measuring the distance from a synchronized radiobeacon and sound-signal station. And it can be used to advantage in many other operations.

## 455. Rangefinder

A rangefinder is an instrument with which the distance of an object may be measured with reference to a short base incorporated in it. In its simplest form it consists of a tube within which are two prisms at the ends of the base, arranged to bring reflected images to a central eyepiece into which the observer looks. The distance between the prisms is the base and the instruments are usually classified by the base length, e. g., a 1-meter rangefinder. The over-all length of the instrument is slightly greater than the distance between the prisms.

A distance is measured by looking into the eyepiece and bringing the two reflected images of the object into coincidence by an adjustment provided to move one with reference to the other. The distance may then be read on a graduated scale which is operated by the mechanism for bringing the images together. The scale is graduated in either meters or yards; which should be ascertained before using a particular instrument.

The rangefinders used in the Coast and Geodetic Survey generally have base lengths of either 30 centimeters or 1 meter, the smaller being used by launch and shore parties and the larger on board the survey ships.

The range and accuracy of a rangefinder vary with the length of base and precision of manufacture. The 1-meter rangefinder is graduated from 250 to 20,000 yards, and the 30-centimeter rangefinder from 20 to 1,000 meters. Table 10 indicates the accuracy to be expected with each instrument.

TABLE 10.—*Probable error of rangefinder distances*

| Distance | Probable error | |
|---|---|---|
| | In 1 observation | In mean of 6 observations |
| *By 30-centimeter rangefinder* | *Percent* | *Percent* |
| 50–100 meters | Less than 1½ | |
| 100–250 meters | Less than 2 | ½ to ¾ |
| 250–500 meters | Less than 3 | ½ to ¾ |
| *By 1-meter rangefinder* | | |
| Up to 1,000 yards | 1 | Less than 1 |
| 1,000–2,000 yards | 2 | 1 |
| 2,000–4,400 yards | 3–4 | 2 |
| 4,400–5,400 yards | 7–8 | 5 |

## 46. DEPTH FINDING EQUIPMENT AND INSTRUMENTS

The instruments and accessories used by the Coast and Geodetic Survey for hand-lead and wire soundings are described in this section. Echo-sounding instruments are described in chapter 5. The wire drag and sweep are described in Special Publication No. 118, Construction and Operation of the Wire Drag and Sweep.

### 461. Sounding Pole

Shallow depths over an extensive tidal flat in protected waters can be measured more easily and accurately with a sounding pole than with a leadline. The soundings are read to the nearest half-foot, but are limited to depths not exceeding 12 feet. Between soundings the pole is not raised out of the water, but is turned end for end, alternately. This permits soundings to be taken faster, provides a close spacing of soundings, and is easy for the leadsman.

The sounding pole is a 15-foot length of 1½-inch round lumber, capped with a metal shoe at each end which may be weighted to hasten sinking. Any convenient system of marking which is symmetrical toward both ends and minimizes errors may be used. The following system has proved satisfactory: Mark each foot and half-foot permanently by a small notch cut in the pole. Paint the entire pole white, and the spaces between the 2- and 3-, the 7- and 8-, and the 12- and 13-foot marks black. Other foot marks are indicated by ½-inch colored bands, red at the 5- and 10-foot marks, and black at the 1-, 4-, 6-, 9-, 11-, and 14-foot marks. Half-foot marks are ¼-inch colored bands, white where the pole is black and vice versa.

### 462. Leadline

A leadline is a length of sash cord or tiller rope to which a sounding lead is attached, and is used for measuring depths of water. It is graduated by fathom or foot marks and seizings. The lead is lowered until it touches bottom and at the instant the line and lead are vertical and taut and the lead is on the bottom, the depth is read from the markings on the leadline.

To avoid large corrections to the observed soundings, it is important to use a leadline material that will not stretch nor shrink with prolonged use. The Coast and Geodetic Survey has adopted, as standard leadline material, mahogany-colored tiller rope with a phosphor-bronze wire center, of six strands of seven wires, each No. 33 B. and S. gage. The wire core should not break with prolonged flexing. The rope is size No. 8, about one-quarter inch in diameter, made of solid-braided long staple cotton, and waterproofed. The braid should be tight so that wire strands that break are less likely to protrude through the rope covering to injure the leadsman's hands.

In 1941, Samson mahogany tiller rope, manufactured by Samson Cordage Works, Boston, Massachusetts, was found to be most suitable. The Washington Office will furnish this material upon requisition.

A lead weighing not less than 8 pounds should be used for handlead sounding in depths to 7 fathoms. For greater depths, a 12- to 14-pound lead should be used. (See **4661**.) For sounding where there are subsurface currents a still heavier lead may be required to ensure vertical casts. A leadsman should not be required to sound with an excessively heavy lead for long periods of time without relief. To avoid subjecting a leadline to different tensions, which may introduce errors in the soundings, the same-sized lead should always be used on the same line.

### *4621. Marking Leadlines*

A leadline should be from 15 to 30 fathoms in length, depending on the depths in which it will likely be used and whether it is intended for use on a small boat or survey ship.

Each leadline should be identified by a consecutive number stamped on a metal disk attached at the inboard end of the line at the time of graduation. This number should be retained throughout the life of the leadline or until it is necessary to re-mark it.

The braided covering of a leadline tends to shrink with use when wet. When this occurs, the wire core eventually buckles, and strands break and are likely to protrude through the covering and injure the leadsman's hands. This can be prevented by the following preseasoning before it is marked:

A leadline is prepared for use by soaking it in salt water for 24 hours. Then while wet it should be laid out where the cotton covering can be worked along the wire by hand until about a foot or so of the wire for each 10 fathoms protrudes from the covering. This is a tedious proceeding, several men have to cooperate, the covering can be pushed back only a few inches at a time, and this length of slack has to be pushed nearly the full length of the line before another few inches can be started. The excess wire is cut off. Experience has proved that a leadline so prepared, if the covering is worked back the correct amount, will maintain an almost constant length in future use. The covering must not be worked back too far or it will form bulges along the wire.

After the above preparation the line should be dried under considerable tension and then soaked again for another 24 hours. A leadline should never be boiled as this removes the waterproofing with which the covering is impregnated.

After the lead has been attached, the line while still wet should be placed under a tension equal to the weight of the lead, while it is being graduated. If temporarily marked at this time the permanent marks can be seized on afterwards.

The marks on a new leadline may be laid off with a tape, but the most convenient arrangement, and one which will be needed later for leadline verification, is to mark the correct distances permanently with copper tacks on the deck of the ship, or on a wharf if the survey party is based at a shore station.

Two units of measure, the fathom and the foot, are used by the Coast and Geodetic Survey for the measurement of depths, but the two units are not commingled on the same leadline. One system of marking utilizes feet only and the other system fathoms and tenths of fathoms. Every survey party that has occasion to use both depth units in accordance with the instructions in this Manual shall be equipped with at least one leadline marked in each unit.

Leadlines in fathoms shall be marked as follows:

| *Fathoms* | *Marks* |
|---|---|
| 1, 11, 21 | One strip of leather. |
| 2, 12, 22 | Two strips of leather. |
| 3, 13, 23 | Blue bunting. |
| 4, 14, 24 | Two strips of leather secured in the middle (so that two ends point upward and two downward). |
| 5, 15, 25 | White bunting. |
| 6, 16 | White cord with one knot. |
| 7, 17 | Red bunting. |
| 8, 18 | Three strips of leather. |

| *Fathoms* | *Marks* |
|---|---|
| 9, 19 | Yellow bunting. |
| 10 | Leather with one hole. |
| 20 | Leather with two holes. |

Between the fathom marks intermediate marks shall be placed, by which fractions of a fathom can be read in tenths. Each half-fathom (0.5) shall be marked by a seizing of black thread and each even tenth-fathom (0.2, 0.4, 0.6, and 0.8) by a seizing of white thread, the odd tenths being estimated.

All fathom marks extend 2 inches from the leadline. All the leather marks should be made in one piece, the strips, about ¼ inch in width, being slit in the free end of the mark. The bunting marks are made by folding a piece of bunting to a size about ⅝ inch wide by 5 inches long; the length of folded bunting is then folded once in the middle and secured to the leadline so the folded end is free.

Waxed linen thread should be used to secure the marks to the leadline. The prepared twine with which golf club handles are wound has proved to be excellent. Marks should be secured to the line so that there is no possibility of their slipping, but the thread should never be inserted through the braided covering of the line. This is unnecessary if the marks are properly secured and it is almost impossible without mutilating either the covering or the stranded wire core. All marks should be secured so that their free ends are up when sounding. Marks so secured will tend to stand out more from the line when it is vertical.

The toggle which the leadsman grasps when heaving the lead may be lashed on the leadline or secured in a clove hitch of the line. In the latter case the toggle must be secured before the leadline is graduated.

The lead to be used with the line, likewise, must be attached while the line is being graduated (see **4661**).

Leadlines in feet shall be marked as follows:

| *Feet* | *Marks* |
|---|---|
| 2, 12, 22, etc | Red bunting. |
| 4, 14, 24, etc | White bunting. |
| 6, 16, 26, etc | Blue bunting. |
| 8, 18, 28, etc | Yellow bunting. |
| 10, 60, 110 | One strip of leather. |
| 20, 70, 120 | Two strips of leather. |
| 30, 80, 130 | Leather with two holes. |
| 40, 90, 140 | Leather with one hole. |
| 50 | Star-shaped leather. |
| 100 | Star-shaped leather with one hole. |

The intermediate odd feet (1, 3, 5, 7, 9, etc.) shall be marked by white seizings. The leathers marking the 10-foot multiples should be identical in size with the fathom marks used on a line marked in fathoms. The bunting marks identifying the intermediate even feet should be slightly smaller in size.

### *4622. Verification of Leadlines*

Leadlines used for sounding shall be verified by the leadsman, supervised by the recorder, before and after each day's work. The leadline should be compared with a standard while under a tension equal to the weight of the lead in water. The standard may be accurately spaced copper tacks in the deck, or in a wharf for a party based ashore, or a steel tape may be used temporarily. At least one extra leadline should be tested and ready for use in an emergency. A leadline should always be wet when tested. When in daily use leadlines should be stowed at night in a tub of water.

Rubber Stamp No. 35, Leadline Comparison, (see fig. 178) must be used in recording the results of the comparison in the Sounding Record. This stamp must be impressed in the Record at the beginning and end of each day's work, and elsewhere whenever a comparison is made. Where the leadline is found to be correct, a simple state-

ment to that effect, such as, "Leadline tested correct to 15 fathoms," is sufficient. Where it is found to be incorrect, the results of the comparison shall be entered under the appropriate headings, for each fathom, or for each 5 feet for a leadline marked in feet. The true length by the standard is entered under the column headed "*D*" and the corresponding length by leadline under the column headed "*M*." The corrections to the recorded soundings are found by subtracting the leadline (*M*) values from the standard (*D*) values.

Corrections must be entered in decimals of the same unit in which the leadline is marked—e. g., for a line marked in fathoms and tenths of fathoms, corrections should be in hundredths of fathoms; for a line marked in feet, corrections should be in tenths of feet.

A leadline should be re-marked when it is consistently in error by an amount larger than that specified in **3111**.

### *4623. Errors in Leadline Soundings*

Errors in leadline soundings are of two general kinds; those resulting from an incorrect depth being indicated by the leadline, and those resulting from an incorrect reading or recording of the depth. The hydrographer must be alert to keep both types of errors at a minimum.

Most inaccuracies of the first type result from a failure to have the leadline vertical and taut at the time it is read. They can be largely eliminated by reducing the speed of the vessel or by heaving the lead farther ahead. Similar errors result from sounding with a leadline in strong currents (see **3464**). An inaccuracy results from a failure of the leadsman to raise the lead off the bottom and lower it again just before the line is vertical. Errors sometimes result from the lead sinking into the ooze or soft mud on the bottom. Unfortunately, all of these errors make the depths seem greater than they actually are. (See also **3421**.)

Errors of the first type will also result from an incorrectly marked or graduated leadline, or from a leadline which varies in length while being used in sounding.

Errors of the second type are entirely personal, and conscientiousness and attention on the part of the leadsman and recorder are the only remedies.

The most common error is due to the recorder's misunderstanding the depth called out by the leadsman. Some launch engines are noisy, and at times orders are being issued or other data called out at the same time the leadsman calls out the sounding. The leadsman should be instructed to call out all soundings loudly and distinctly, facing the recorder as he does so; and the recorder must repeat every sounding, for a check, as he enters it in the Sounding Record. Such errors are usually due to a confusion of similarly sounding numbers, such as 7 and 11, 5 and 9, 15 and 50, etc. Careful enunciation will eliminate such confusion. The *-teen* numbers should be equally accented on both syllables, as **fif′-teen′**, but the *-ty* numbers should be strongly accented on the first syllable only, as **fif′**-ty. The first syllable of *eleven* should be strongly stressed and prolonged, as **ee′** -leven, to distinguish it from *seven* in which the *s* should be overemphasized, as **ss**—even. The *v* in ***five*** and the second *n* in *ni***n***e* should be enunciated plainly. Where the leadsman and recorder, and at least one of the anglemen, are bilingual, as in the Philippine Islands, the best assurance against such errors is to have the depths called out in English and repeated by the recorder in Spanish, or vice versa.

Leadsmen should be instructed in heaving the lead and in reading the leadline; the work of a new leadsman should be closely supervised until he is proficient. Close attention to his duties will eliminate inaccurate readings. When an unexpected depth is called out by the leadsman, the recorder should immediately ask that it be checked.

Errors in soundings are also discussed in **774**.

### *4624. Ship Sounding Chair*

A sounding chair (also sometimes called *the chains*) is an elevated platform on which the leadsman stands when taking a handlead sounding. A ship sounding chair should have the following characteristics:

(*a*) It should be located well forward of amidships, preferably near the bridge. The leadline can be heaved better from this location, and it permits the leadsman, recorder, and observers to be stationed near one another.

(*b*) It should extend over the water far enough to ensure that the lead, when swung in taking a sounding, will be well clear of the side of the ship.

(*c*) It should be at least 18 or 20 feet above the water, if practicable, so that a leadline with a toggle attached at the 18-foot mark will not strike the water, when swung.

(*d*) The platform of the chair should be sturdy and well braced. If formed of a grating, the openings must be small enough so that the leadsman's shoe cannot possibly catch in them. The edge of the platform must be arranged so that the leadsman cannot accidently step off it.

(*e*) The sides of the sounding chair should be about 3 feet high, padded around the top to provide the leadsman with something to brace himself against, and covered with canvas to protect the leadsman from the spray from the leadline.

(*f*) The chair should be demountable so that it may be removed, or swung inboard, to be out of the way in docking the vessel.

(*g*) A survey ship should have two sounding chairs, one on each side, for the use of right- and left-handed leadsmen, and when soundings need to be taken so rapidly as to require two leadsmen simultaneously.

### *4625. Launch Sounding Chair*

A sounding chair for use on a hydrographic launch should have the same general characteristics as a ship sounding chair, except that it should be proportionally smaller and lighter for a small launch. The principal difficulty on a launch is to obtain sufficient elevation for the swing of the lead. On a launch with a deckhouse this can be attained by extending the platform from the top of the deckhouse and bracing it against the side of the hull or the guardrail. Vertical soundings in depths of 15 to 20 fathoms can be obtained from an installation of this type at regular sounding speed.

FIGURE 79.—Sounding chair extended from top of deckhouse.

For temporary use on a small launch, a standard 55-gallon oil or gasoline drum, secured to the gunwale or bulwark, makes a satisfactory sounding chair, easily and quickly installed. It is especially satisfactory for sounding in depths of water less than 8 or 10 fathoms. The top is cut away and the inboard side of the drum is cut down to afford easy entrance and exit. A length of ordinary garden hose, split open, should be secured over the upper edge to protect the leadsman.

For a whaleboat a satisfactory sounding chair can be provided by a small platform built of 2- by 4-inch lumber, which is laid across the gunwales of the boat just aft of the

forward hoisting bolt. The platform is fastened to both gunwales and extends outboard on one side just enough so that vertical leadline soundings can be taken from it. A framework of 2- by 4-inch lumber is usually built at the outer end of the platform and well braced inboard to the platform itself. Canvas can be placed around the framework to protect the leadsman from spray.

Should it be inconvenient or impracticable to install a regular sounding chair on a launch or small boat, a canvas belt may serve temporarily to support the leadsman while sounding. A small hinged platform is built and secured to the deck of the launch. A 6-inch belt made of canvas is passed around the waist of the leadsman and secured to the launch where convenient, as to pipe frames, stanchions, or handrails. This belt will not only support the leadsman but will also give him enough freedom of action to heave the lead without fear of falling overboard. It does not furnish protection against spray.

## 463. Sounding Machines

A sounding machine is a mechanical device, operated either manually or by power, used to measure, with wire, depths of water too great for the handlead. The apparatus consists of a reel mounted on a stand, with a means for applying power and a brake for stopping the reel. It is used for taking vertical wire soundings, for comparisons with echo soundings, and for obtaining oceanographic data such as bottom specimens, water samples, and temperatures.

The sounding wire which is wound around the reel, the registering sheave to measure the amount of wire run out and over which the wire passes, and the weight attached to the end of the wire, constitute the depth-measuring equipment. The wire is led over the side or stern of the vessel through a system of sheaves or pulleys, one of which is the registering sheave.

The operation of taking wire soundings and the speed of operation are described in **3422**, and the operation of observing water temperatures is described in **6321**.

### *4631. Ship Sounding Machines*

The Coast and Geodetic Survey has developed and adopted as standard two types of sounding machines, although many different types, such as the Lucas, Sigsbee, Lietz, Tanner, and Kelvin have been used in the past. The two types are known as the deep-sea machine and the LL-type machine; they are basically the same in construction and operation, differing principally in size of reel. Their speed, smoothness, and ease of operation are believed to be superior to those of other types. Piano wire is usually used on the deep-sea machine and stranded wire on the LL-type machine, although either kind of wire can be used on either machine. Drawings and specifications of the machines can be obtained from the Washington Office when needed.

The basic description of both types of machines is as follows: A reel is mounted so as to turn freely on a control shaft which has a collar by means of which the reel can be slid from one side to the other by a handle. On one side of the reel a brake disk is secured to the frame of the machine and on the other side of the reel a clutch disk is attached to a shaft to which is also attached the power pulley or gear. The brake and clutch disks are beveled and covered with a preformed Raybestos brake lining. The control shaft has a worm screw cut in one end which causes it to shift in and out longitudinally when the end of the operating handle is moved from side to side.

When the machines are electric-driven a 3 horsepower, watertight Diehl electric motor is used; the motor is ball-bearing, compound-wound, interpole, variable speed

ranging from 500 to 1,500 r. p. m., operating on 110-volt direct current. Speed is controlled by a Cutler-Hammer field rheostat with 12 to 14 steps of field control and a no-voltage release which automatically turns the control arm to slow speed if, for any reason, the current is cut off.

Power transmission has been by gears, a silent chain, or a V-shaped belt. The V-belt drive, on account of its silence, is preferable when it can be used.

The operation of the machines is simple. When the control handle is vertical, the reel is in neutral and is free to turn, and the wire will run out. To stop the wire running out, the handle is moved to one side, shifting the reel to where it engages the brake. If the control handle is moved to the opposite side the reel will engage the clutch. The engagement with either brake or clutch may be abrupt or gradual according to the force

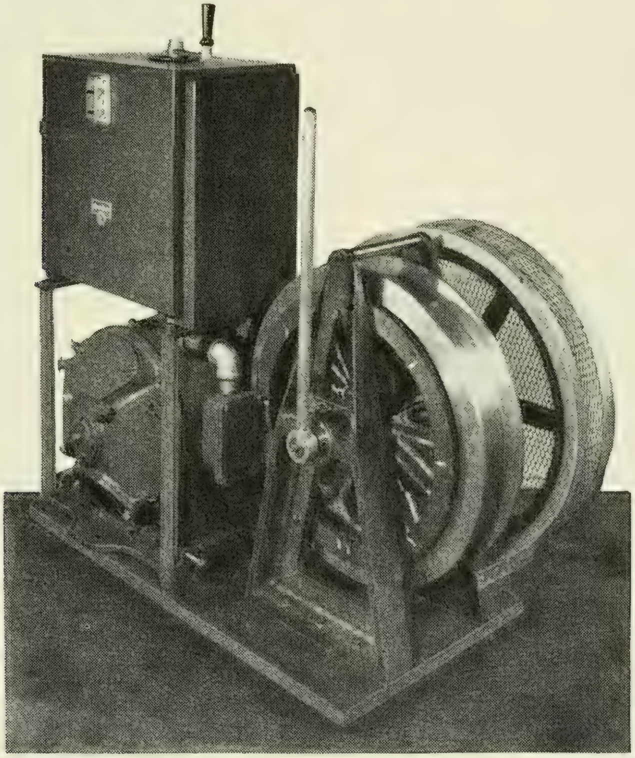

FIGURE 80.—Deep-sea electric sounding machine.

applied to the handle. The clutch should always be idling at slow speed—never stopped—at the time the reel engages it.

*Deep-sea sounding machine.*—Each survey ship has at least one deep-sea sounding machine. The reel of this machine has a mean circumference of about 1 fathom and will hold about 6,000 fathoms of piano wire. The reel is usually made of duralumin because its lightness reduces the momentum of the revolving reel, but some reels have been made of cast steel. This machine is almost invariably electric-powered. The weight of this machine complete with duralumin reel, electric motor, frame, base, etc., is about 1,275 pounds.

The machine is usually installed on the bridge, the wire being led outboard over the ship's side by fair-leads on a boom (see **4633**). There is usually a revolution counter,

but this is not used for depth measurements on account of the varying circumferences of different amounts of wire on the reel. The registering sheave is usually mounted above the machine.

Such machines have been used only intermittently in recent years since the adoption of echo sounding, but their successful operation is evidenced by 6 weeks of continuous deep-sea sounding by one ship in 1923, in depths to 4,600 fathoms, without loss of any wire or equipment.

The LL-*type of sounding machine* is used on practically all survey ships and all auxiliary vessels where a power-driven machine is needed. The reel has a mean circumference of about ½ fathom and will hold about 900 fathoms of stranded wire or about 2,700 fathoms of piano wire. The reel is usually made of bronze. When used on survey ships it is almost invariably electric-powered, but it may be powered by a steam motor, like the Dake motor, or by a stationary gasoline engine, or driven from the gasoline engine of a launch (see **4633**). The weight of this machine complete, with bronze reel, electric motor, frame, base, etc., is about 975 pounds; without motor and power transmission its weight is about 175 pounds. The L-type of sounding machine is an older model of the LL-type, differing from it only in minor details.

This same machine is used on launches where a power-driven sounding machine is needed, although many other types have been used in the past.

An *automatic brake sounding machine* has also been developed by the Coast and Geodetic Survey. Its principal characteristic is that the brake is automatically applied by means of a series of triggers and springs the instant the wire slacks when the lead strikes bottom, but it requires a fine adjustment to ensure against the brake being applied at other times. Its cost is much higher than that of the LL-type.

### *4632. Hand Sounding Machine*

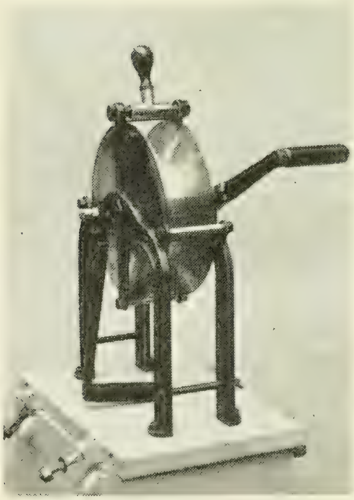

FIGURE 81.—Hand sounding machine.

The hand sounding machine most extensively used by the Coast and Geodetic Survey is similar to those used on commercial vessels and is illustrated in figure 81. It has a bronze reel and brass standards. The brake is a wood-lined clamp, either forced against the reel, or released, by a small handle above the reel. The handles are so hinged that they can be disengaged from the shaft while the wire runs out and engaged for reeling in. The machine is mounted on a wooden base provided with clamps. Its box may be used as a cover for the machine, or as a support for it when in use.

The machine is used for depths from 10 to 150 fathoms. It is usually mounted on the stern of a ship's launch, with a sheave overhanging far enough to keep the wire well clear of the stern and the propeller. Where many wire soundings are to be taken a power machine should be requisitioned and installed.

### *4633. Installation of Sounding Machines*

A ship sounding machine is usually installed on or near the bridge with the wire leading outboard over the side, where the officer-in-charge can supervise the operation

and watch the wire at all times. With it in this position the ship can be maneuvered at will to keep the wire vertical while sounding. A fair-lead should be carried on a davit or boom to lead the wire well clear of the side. The registering sheave, or counter, should be mounted near the machine where it can be conveniently read by the operator. A satisfactory installation is indicated in figure 82. The wire is led through a fair-lead on a boom of 2½-inch galvanized iron pipe. The fair-lead is attached to a pipe cross which turns freely on the boom, and is rigged so it can be slid along the boom and used in any position when sounding. The fair-lead is counterbalanced by an

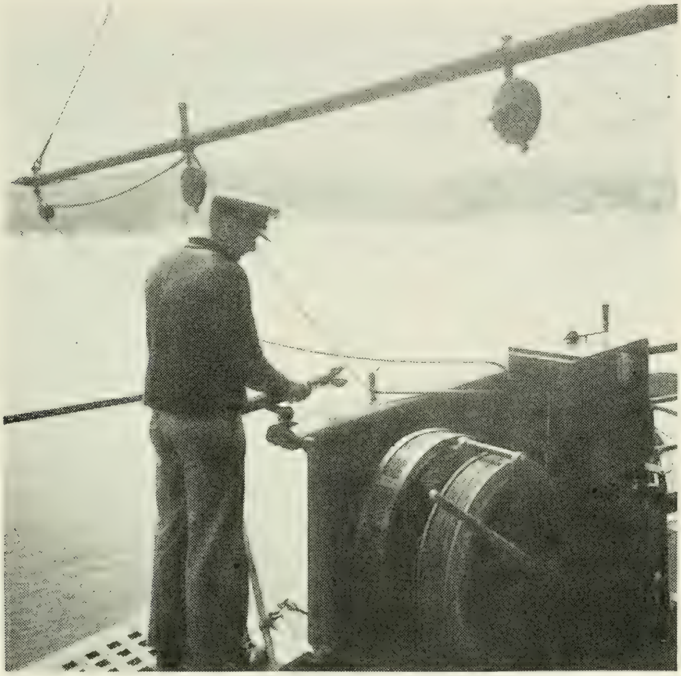

FIGURE 82.—Installation of ship sounding machine.

adjustable weight at the top of the cross. The registering sheave may be seen in the figure on the boom above the sounding machine. A rocker arm (not shown in the figure) is usually hinged at one end to the machine or rail and has a small pulley at the other end which rides on the wire. The weight of this arm continuously takes up any slack and by a sudden drop indicates clearly when the lead strikes bottom.

An accumulator spring, between the end of the boom and the stay supporting it, serves the double purpose of easing the strain of sudden surges due to rolling or pitching of the vessel and indicating the tension when reeling in. The tie rods of this spring are marked to show each 25 pounds of tension up to 150 pounds. This spring should be used with piano wire for depths greater than 200 fathoms and the speed of reeling in should be regulated so that the tension does not exceed 100 pounds.

On account of the wide variation in survey launches and their power plants, no one standard method of sounding-machine installation can be specified. The wire is usually led through a sheave mounted on a davit overhanging the stern, although there is an increasing tendency to lead the wire over the side amidships. Where the stern mounting is used the registering sheave is usually on a davit which overhangs just

enough to ensure that the wire will clear the stern and not likely be fouled by the propeller. Where the wire is led amidships, the arrangement is similar to that used on survey ships. A boom is rigged of different sizes of pipe, which will telescope into one another and be out of the way when not in use. The registering sheave is inboard with a fair-lead on the outer end of the boom. The advantages of the midship installation are that one of the anglemen can supervise operations more closely and can verify the sheave reading more conveniently, and it is more conveniently located for reading a thermometer for the temperatures required in a launch echo-sounding survey.

A hand sounding machine may be located in any convenient space, usually on the stern, where there is room for the men needed to operate it. The location of a power-driven machine depends more on the type and location of the power plant of the launch. It is usually more satisfactory to derive the power from the forward end of a gasoline engine, as this interferes less with its operation. For this reason the sounding machine is usually installed inside the hull near the forward end of the engine, if there is available space for it. It is then connected to the engine either by a belt or chain drive to the flywheel, or by a system of gears and shafting to the jackshaft. Where installed on the stern deck the connection is to the clutch shaft. A V-type of leather belt drive is preferred to any other type of drive because it is much more silent in operation.

Any power machine should be bolted through the deck beams or secured to a base plate which itself is bolted through the deck beams. Where the sounding machine is installed forward of the engine and sounding from the stern is preferred, the wire may be led overhead through two fair-leads suspended from the canopy and through a window cut in the canopy to a registering sheave astern.

### 464. Registering Sheaves

A registering sheave is a device used to measure the amount of wire payed out when sounding. It consists of a grooved wheel (circumference 23.911 inches) mounted

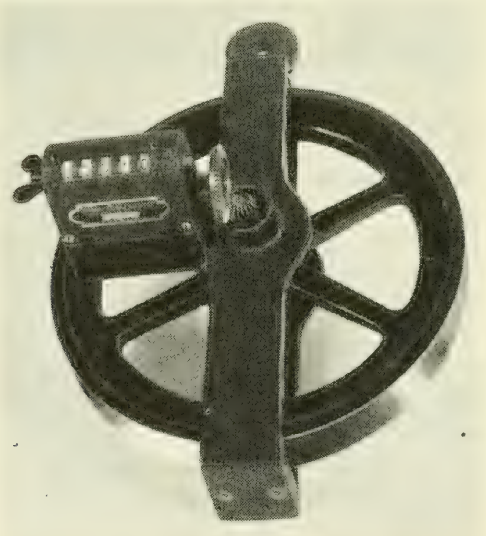

FIGURE 83.—Registering sheave.

in a yoke so that it will revolve freely, and connected by gears to an indicator on which the number of fathoms of wire run over the wheel is indicated. The preferred type of indicator is a counter, the numerals of which indicate fathoms and tenths of fathoms.

and which can be reset as desired. It is geared to the shaft of the sheave by bevel gears and is positive acting. The older type of indicator is merely a pointer moving around a dial and is connected to the shaft by a worm gear. Any side play of the wheel in the yoke decreases the accuracy of soundings measured with this type of indicator.

Only one size of sheave is used and its circumference is such that when piano wire is used one revolution will measure exactly 2 feet, or ⅓ fathom. When stranded wire is used on this sheave each reading will be in error by about 0.5 percent because of the larger diameter of the stranded wire. The readings are too low by 0.48 percent, or about 34½ inches in 100 fathoms. All soundings measured with stranded wire should be corrected by the sheave factor. For most other purposes an error of this magnitude will be negligible, but a correction can be made where necessary.

In sounding, the wire must be in contact with the bottom of the groove in the sheave for at least one complete turn to prevent slipping. With the usual arrangement there is from 1¼ to 1½ turns of wire on the sheave.

A registering sheave in good condition should never be used solely as a fair-lead. Cheaper devices should be used for this purpose, but if not available, a registering sheave that has been discarded as a measuring device because of wear or inaccuracy may be employed.

### *4641. Registering Sheave Calibration*

A registering sheave must be calibrated before it is used for deep soundings or any other purpose requiring much accuracy, and the calibration should be verified several times during the season, if it is used extensively. The sheave may be calibrated most accurately by running the wire over it for an accurately measured distance along a wharf or other level space. A spring balance should be used to apply a tension to the wire during the test equal to the tension on it while sounding.

Another, but less accurate, method is to measure the circumference directly by stretching several turns of wire around the sheave, marking it, and measuring the length of the wire when laid out straight. The marks on the turns of wire must be parallel to the axis of the sheave. This is similar to one of the methods described in **4467** for calibrating the taut-wire apparatus, and the same precautions should be observed. When this method is used to calibrate a sheave with the pointer-and-dial type of revolution counter, a verification of the counter is also required. The sheave should be marked and turned a definite number of revolutions and the counter read for different numbers of revolutions. The measured circumference multiplied by the sheave revolutions will give the actual distances represented by the counter readings.

Correction factors, known as sheave factors, should be computed for piano wire and stranded wire, if both are likely to be used. With the type of sheave now used, the correction for piano wire is usually negligible, and the correction for stranded wire will closely approximate plus 0.48 fathom per 100 fathoms (see **464**).

The sheave factors should be reported in the pertinent Descriptive Reports and special reports.

### *4642. Sheave Wear*

The accuracy of a registering sheave is impaired when it becomes loose in its bearings, or is scored by the wire. After a sheave has been in use for some time it should be tested more frequently and be no longer used as a measuring device when proved unreliable. Worn sheaves may be used as fair-leads or returned to the Washington Office. A sheave should be oiled frequently and properly, and should always be handled care-

fully. Every precaution should be taken to prevent the wheel from jamming in its yoke, as this will frequently result in the wheel being scored by the wire.

Sheaves with worm gears develop side play in the yoke when worn. This may cause an error of as much as 1 fathom in the dial reading. Therefore, when special accuracy is required, as in comparative soundings, a fairly new and carefully calibrated sheave should be used. Should it be necessary to use a sheave with side play, the wheel should be held against one arm of the yoke when setting the pointer, and against the same arm when reading the depth.

In the counter-type of sheave there is no worm gear, so there should be no error due to side play.

## 465. Sounding Wire

Two types of sounding wire—stranded and piano—are ordinarily used for wire soundings. Stranded wire should be used in depths less than 300 fathoms; piano wire should be used in greater depths. For the use of wire with sounding machines, see **3422** and **463**.

### *4651. Stranded Sounding Wire*

Stranded sounding wire is composed of seven tightly twisted strands of double-galvanized No. 24 B.W.G. gage wire, and has a breaking strength of not less than 500 pounds. It is furnished in 300-fathom lengths, packed with powdered lime in sealed cans. The diameter of stranded sounding wire is 0.065 inch.

### *4652. Piano Wire*

Piano sounding wire is single No. 21 B. and S. gage steel wire. It is furnished in 2,000-fathom lengths, packed with powdered lime in sealed cans. Its diameter is 0.0285 inch. Although it has a breaking strength of approximately 190 pounds, it should not be subjected to a tension greater than 100 pounds when reeling in.

The lead should not be attached at the end of piano wire for taking soundings, because the wire is apt to kink when the lead strikes the bottom and to part when reeled in. To avoid this a 25-fathom length of stranded wire or a few fathoms of small Manila line should be inserted between the end of the piano wire and the lead. If a sounding machine with piano wire is used for taking serial temperatures, a 150-fathom length of stranded wire should be inserted between the end of the piano wire and the lead, because most such observations are taken in depths less than 150 fathoms and there is less risk of the stranded wire parting.

### *4653. Splicing Stranded Wire*

Stranded sounding wire is seldom used in depths exceeding 300 fathoms, and new wire is furnished in such lengths. Ordinarily it is not economic to splice it, except where it must be used for deeper soundings, or when there is a shortage of wire.

Where it becomes necessary to splice stranded wire, a regular long wire splice should be made, with the wires ending at varying distances apart throughout the length of the splice. The ends should be tucked and the splice seized with fine copper wire at both ends and one or two places in the middle. The whole should be cleaned with muriatic (hydrochloric) acid and washed with solder. The solder coating must be quite thin to avoid making the splice too stiff.

### *4654. Splicing Piano Wire to Stranded Wire*

Piano wire may be spliced to stranded wire by unlaying one of the wires of the stranded wire for a distance of about 4 feet and laying the piano wire in its place. The splice should be seized with fine copper wire at each end and at intervals of about a foot, and the entire splice should be cleaned with acid and soldered. The piano wire has a tendency to spring out of the splice unless seized at short intervals.

### *4655. Splicing Piano Wire to Manila Line*

Manila line is often used as a stray line on the end of piano wire. These can be joined as follows: Tie a single wall knot at the end of the Manila line, and run the piano wire through its center. Tighten the knot, wind the piano wire around the line against its lay for about 10 or 12 turns, and tuck it through the line. Reverse the direction and wind the wire around the line with the lay for 10 or 12 turns. Tuck the wire through the line once again and wind it against the lay of the line for an additional 10 or 12 turns. Tuck the end of the wire, and seize the end of the splice.

### *4656. Splicing Piano Wire to Piano Wire*

Piano wire can be spliced in either of two ways. Although it requires more time the following method is far more satisfactory and durable and should always be used for making permanent splices: Overlap the two ends of wire for a distance of about 10 feet, with both wires fairly taut. Seize the wires temporarily with sail twine at one end of the overlap and then wind the free wire end around the other wire in a long spiral with about one turn in 2 inches, keeping both wires taut during the procedure. Then seize the other end of the splice temporarily and examine to ensure that the two wires are contiguous throughout the entire length of the splice. Then with fine copper wire seize each end of the splice for a distance of 2 inches, continuing for a short distance along the single wire. Next place two 2-inch seizings so as to divide the splice into three equal parts. Clean all seizings with muriatic acid, wipe with soldering paste, and cover each with a thin coat of solder.

For emergency repairs to piano wire while sounding, the following alternate method may be preferable, as it requires less time than the one described above: Anneal the end of each wire for a distance of about 2 inches. Then overlap the two wires and wind one around the other in long spiral turns for a distance of about 2 feet. At each end of the splice wind the annealed end of wire in close turns around the other wire. Clean the entire splice with muriatic acid and wipe with soldering paste. Prepare a shallow trough by grooving a piece of timber somewhat longer than the splice. Fill the trough with molten solder and dip the entire splice in the solder. Wipe the splice with folded felt, or other heavy material, greased with tallow, sperm candle, or sweet oil.

### *4657. Placing Sounding Wire on Machine*

Placing new sounding wire on the reel of a sounding machine is quite difficult. The coiled wire, especially piano wire, once out of control becomes hopelessly snarled. With patience, stranded wire can sometimes be unsnarled, but it is invariably a waste of time to attempt to straighten out piano wire once it is out of control.

The use of a wooden cone, as described below, is almost essential in handling piano wire and it expedites handling stranded wire. By its use a coil of stranded wire can be

transferred to the sounding machine by power, and with experience and care the same method can be used with piano wire.

A conical-shaped wooden frame, 2½ to 3 feet high, should be constructed, built around an iron rod running through its center, on which it revolves as an axis. The diameter of the base of the cone should be about 1½ times the outside diameter of the largest coil of wire to be used on it. With these dimensions a coil of piano wire should rest about halfway between the apex and base of the cone, a coil of stranded wire resting somewhat higher.

Two wooden blocks with metal sockets should be built to serve as upper and lower bearings for the iron rod. The lower block may be secured temporarily to the deck in any convenient place and the upper block secured to a cross brace, so that the cone is held securely between them in a vertical position, yet can revolve freely. A rope brake is used, one end of which is secured and the other end held in the hand of an operator, with about a three-quarter turn around the cone.

The wire is led off the cone *downwards* and under a horizontal bar of wood, thence upward over another similar bar at least 5 feet above the deck, thence horizontally for a distance of about 10 feet to a sheave directly over the sounding machine, and onto the reel. A sliding weight is placed on the wire between the higher of the two bars and the sheave. This weight must be kept from sliding toward the sheave by a light cord secured in the direction of the cone. The purpose of the sliding weight is to take up the slack in the wire between the bar and the sheave at all times, otherwise piano wire will surely kink sooner or later. This slack in the wire is also a safety factor, which gives the operator of the reel time to stop it, if the wire jams at the cone.

The sounding machine is started slowly either by hand or power. The men at the machine and the rope brake watch the sliding weight constantly and are guided by its position. The machine should be run at constant speed and any variations in tension counteracted by the use of the rope brake. The brake is applied whenever the sliding weight begins to fall, and slacked as it rises. Some experience and constant attention are required, especially if the machine is to be run by power. The man at the machine must be ready to stop it instantly if the sliding weight rises quickly, for this may indicate that the wire is jammed at the cone and, if so, the wire will be parted if the machine is not stopped.

It is immaterial which end of a coil of wire is led to the machine, so long as the end is clear. Soon after starting, the wire appears to come from the inside of the coil and will continue to appear so until the entire coil is on the drum.

A supply of wire may be carried on a storage reel, from which it can be transferred to the sounding machine by power in a much shorter time than is required to rig and use the cone for a new coil of wire.

### *4658. Care of Sounding Wire*

Even galvanized sounding wire is likely to rust, unless properly cared for. At the end of a field season, or at any other time when the wire is not to be used in the near future, it should be run off the sounding machine reel, and thoroughly dried and oiled when replaced. The surface of the reel, and any part which comes in contact with the wire, should be well dried and freely coated with mineral grease, before rewinding the wire. The reel of wire should be well wrapped with oil-soaked cloths.

When in use, and especially after the last sounding of each day, the wire should be run through a piece of well-greased canvas as it is reeled in. A brush dipped in

heavy oil or hot tallow should be held occasionally against the wire on the reel, while reeling in, for additional protection.

The sounding machine itself should be protected by a canvas cover when not in use.

The original cans of wire should not be opened until the wire is needed. When a can is opened, either all of the wire should be put on the sounding machine or the unused remainder should be wrapped in oiled cloths before it is stowed away.

## 466. SOUNDING LEADS AND WEIGHTS

Sounding leads are weights attached to the leadline, or sounding wire, for the purpose of carrying it to the bottom, so that a vertical measurement of the water depth can be made.

The proper weight of lead for use in handlead sounding is given in **462**. Weights varying from 14 to 110 pounds are used with sounding wire depending on the depth. In depths from 15 to 100 fathoms a lead weighing 14 to 25 pounds should be used for launch wire sounding. With a ship sounding machine a 35-pound lead should be used for depths to 1,000 fathoms, which is about the maximum depth from which it is practicable to recover the weight without risk of parting the wire. In depths greater than 1,000 fathoms, a detachable, pear-shaped, cast-iron sinker weighing about 65 pounds is used with a detaching rod. When this strikes the bottom the sinker is detached and remains on the bottom. The strain on the wire is thus decreased when only the detaching rod is brought back to the surface.

### *4661. Sounding Leads*

Sounding leads in the standard weights of 5, 7, 9, 14, 25, 50, and 80 pounds can be requisitioned from Naval Supply Depots, and other weights can be purchased commercially. Molds can be made up, if desired, and kept on board for use in making leads. Leads should be 1½ to 2 inches in diameter, the length varying with the weight. There should be a cup-shaped depression in the bottom of a lead to receive tallow, soap, or other arming material used to obtain bottom samples. The upper end of the lead should be shaped like an eye, to which the line or wire is made fast.

The preferable method of attaching a lead to a leadline is to make the leadline with a galvanized thimble at the lower end to which the lead is attached by a shackle. Some leadsmen prefer to use a piece of leather between the lead and line, or the line itself may be passed twice through the eye in the lead, doubled back against the standing part, and seized in several places. Whichever method is used, the lead must be attached to the line when it is marked, and thereafter if the end of the line wears so that a piece of it must be cut off, the line must be re-marked.

In sounding where the bottom is hard or rocky, the lower end of the lead will soon be flattened and spread out; it must then be hammered or trimmed to its original shape, as a misshapen lead will sink more slowly.

### *4662. Lead for Rocky Bottom*

An effective sounding weight for use where the bottom is hard or rocky is made by filling a section of heavy galvanized iron pipe with molten lead. The pipe should be 1 to 2 inches in diameter, depending on the weight desired. For use in attaching the pipe lead to the wire, a U-shaped $\frac{3}{16}$-inch rod or the end of a short length of chain should be set in the lead as it cools. A snapper, described in **4761**, may be inserted in the

bottom of the pipe lead, or an ordinary lead for that matter, for obtaining bottom samples.

### *4663. Lead for Very Soft Bottom*

A special lead can be made for use in ooze or very soft mud. An iron rod, ½ by 10 inches, with an eye in one end, is threaded throughout its length. A perforated wooden disk, reinforced by steel bands, is attached just below the eye. Below the disk, 2- to 4-pound sections of sounding lead drilled through the center are screwed on the threaded rod. The whole is held in place by a nut above the disk and one below the lead. Any desired weight of lead and size of disk may be used but a 7-inch disk and 10 pounds of lead will usually be found satisfactory. The leadline should be graduated from the top of the disk.

### *4664. Arming the Lead*

The sounding lead is *armed* to bring up for inspection specimens of the bottom. The depression, or grooved-out hole, in the bottom of the lead is filled with soap, tallow, or a mixture of both. Sand, mud, shells, and pebbles will adhere to these materials and be brought to the surface for inspection so that a description of them may be recorded in the Sounding Records. Some types of mud will not adhere to tallow or soap, in which case the snapper should be used. The sample of deposit brought up is but superficial, and is no criterion of what lies beneath. (See also **384** and **476**.)

### *4665. Detaching Rod and Sinkers*

The Belknap-Sigsbee specimen cylinder, commonly known as a detaching rod, is a device which disengages a sinker when it strikes bottom. The sinker is suspended on a trigger, or tumbler, which is tripped when the bottom of the rod strikes bottom. The sinker is then automatically detached. The detaching rod with sinker should be used for all wire sounding in depths greater than 1,000 fathoms. (See also **4744**.)

The sinker is pear-shaped, specially cast. Drawings and specifications are available for various sizes weighing from 35 to 110 pounds, although the size ordinarily used weighs 65 pounds. This size is about 8 inches in diameter at its widest point. A hole, 2½ inches in diameter, runs vertically through the center, through which the detaching rod is inserted. A wire ear or hook is cast on each side of the sinker slightly above the middle, to which a wire sling is attached. The sinker is hung from the trigger of the detaching rod by this wire sling. To decrease strain on the sounding wire and machine the sinker is detached and left on the bottom.

Another type of detaching weight for use with a snapper is described in **4761.**

## 467. TIDE GAGES

A tide gage is an instrument for measuring the rise and fall of the tide. Tide gages may be divided into two classifications—nonregistering gages which require an observer to record the heights of the tide, and self-registering, or automatic, gages which automatically record the rise and fall of the tide while unattended. Both types of tide gages are fully described in Special Publication No. 196, Manual of Tide Observations.

The Coast and Geodetic Survey uses two principal kinds of automatic tide gages which record the tide in the form of a graph. The standard automatic tide gage is designed for use at primary tide stations, or at stations where observations are to be

continued for long periods of time. The portable automatic tide gage is designed for use at tide stations which are to be continued for only short periods and where ease of installation is an important factor.

Special Publication No. 196 contains detailed information relative to the construction, and instructions for the installation and operation, of both types of automatic tide gages. The requirements with respect to the installation and operation and the submission of data shall be fully complied with.

Any automatic tide gage should be visited and inspected frequently enough to ensure continuous operation, especially during actual hydrography. The standard automatic gage, once successfully installed, should give satisfactory results if the daily comparison and inspection called for in Special Publication No. 196 are made. The portable automatic gage should be visited at least every other day, if practicable, despite the fact that it is driven by an 8-day clock and should operate normally without attention for a week. The possibility of long hiatuses in the record will be avoided by so doing. The record should be changed every fourth day to preclude an erroneous interpretation of a maze of curves.

### *4671. Operation of Tide Gage*

Before installation and after operation, a tide gage should be thoroughly overhauled, cleaned, and oiled, with particular attention being paid to the pencil arm and bearings. The pencil arm should also be cleaned periodically during operation, using kerosene or unleaded gasoline for the purpose.

All the difficulties which might arise cannot be anticipated. Those most commonly encountered are listed in paragraphs 147 to 155 of Special Publication No. 196. It is very important that the float well or pipe be vertical to keep the float from rubbing or catching on its sides. The inside dimensions of the float well of a standard automatic gage should be not less than 12 inches square. The diameter of the float is 8½ inches and a smaller float well will not provide enough clearance, especially if it is not exactly vertical.

### *4672. Tide Station Records*

The location of the tide station to be used for the reduction of soundings must be entered in the Sounding Record in the appropriate space in rubber Stamp No. 38 at the end of each day's work (see fig. 183). If more than one tide station is to be used on the same day, the time when the change from one station to another is effective shall be noted in the Record. Any height or time correction to be applied to the tidal data to refer them to the locale of hydrography for use in reducing soundings shall also be indicated in the Record.

Field parties must scale the necessary hourly heights from the marigrams before forwarding them to the Washington Office. When the plane of reference is needed for the reduction of soundings, it should be requested from the Office. (See also **1215** and **143.**)

The method of tabulating and reducing tide records is described in paragraphs 199 to 258, Special Publication No. 196, Manual of Tide Observations. Field parties will ordinarily tabulate and reduce only those records needed for tide reducers for the hydrography.

## 47. OCEANOGRAPHIC INSTRUMENTS

The instruments chiefly used in hydrographic surveying are those designed for the determination of positions and the measurement of depths. Other instruments are required, however, to measure the temperature and salinity of sea water. These essential data are required to compute the theoretical velocity of sound for use in R.A.R. and to correct the echo soundings. Other special instruments are used to obtain samples of the bottom material so that bottom characteristics may be charted.

The thermometers used to measure the temperature of sea water are of a special design that will record temperatures at various selected depths between the surface and bottom. The salinity of sea water is determined from specific gravity measurements made with hydrometers placed in water specimens which are trapped at various depths in special instruments known as water bottles. Bottom samples are also obtained by means of special instruments which enclose samples of the bottom material, which may then be raised to the surface for examination and a record of the characteristics.

Oceanographic instruments are usually made of nickel-plated brass which is little affected by the corrosive action of salt water in which they are frequently submerged. They must be thoroughly rinsed in fresh water after use, after which they should be dried with a cloth. All moving and hinged parts and screw threads should be lightly oiled occasionally to ensure perfect working condition. When not in use, the instruments should be stowed in a safe place where they will not be damaged. Thermometers should be removed from the instrument frames and stowed very carefully in their wooden cases.

Oceanographic instruments should be tested before use to ensure that they will function as intended. Unless an apparatus is adjusted properly it may have to be raised an excessive distance before it reverses or closes as intended. It may be tested by being lowered 2 or 3 fathoms below the surface to observe the action when it is raised. An instrument in proper condition and adjustment should reverse or close in this distance. If it does not, it should be adjusted before further use or returned to the Washington Office for repairs.

The ingenious apparatus devised by Hooke in 1660 has been utilized as the fundamental principle in all sampling devices, and few improvements of importance had been made until recent years. Recent improvements, however, have been made in the design of many oceanographic instruments which not only permit quicker measurements but also furnish more positive and accurate results. The bathythermograph (**473**), the multiple sea sampler (**4743**), and the Piggot gun (**4764**) are examples of these recent developments. Further innovations are to be expected and the hydrographer should be ever alert not only to improve existing oceanographic instruments but also to envisage the possible development of new ones.

### 471. DEEP-SEA THERMOMETERS

A thermometer used to measure the temperature of sea water must be of special design since it must not only register the temperature at any depth, but must maintain the record until raised to the surface, where it can be read. There are two general types of thermometers used for this purpose. The first is the reversing type. This is the most accurate, and it is the easiest to use. Reversing thermometers are of two types, protected and unprotected from the pressure of the water. The protected type is made with or without an auxiliary thermometer to measure the temperature of the enclosed column of air.

The second type of deep-sea thermometer is an ordinary thermometer mounted in a special water bottle (**4716**), insulated to maintain the temperature constant while it is being brought to the surface.

### *4711. Protected Reversing Thermometer*

The type of deep-sea thermometer in general use by the Coast and Geodetic Survey is the protected reversing thermometer without an enclosed auxiliary thermometer. It is a delicate instrument of expert workmanship. The thermometer is of special design and so constructed that the column of mercury in the capillary tube is parted when the instrument is inverted. This thermometer is illustrated in figure 84 in the position in which it should be lowered into the water. The entire thermometer is enclosed in a heavy glass case *A* to protect it from the pressure of the water. The glass capillary tube *B* is held in place at its upper end by a rubber ring or metal clasp *C* and at its lower end by a special composition seal *D* that also serves to incase sufficient mercury in the lower end to surround the mercury reservoir *E* of the thermometer, providing for rapid temperature conduction from the surrounding water. The special features of the thermometer are: A knife-edge in the capillary tube at *F* which is made by an appendage in the tube; a gooseneck which may take the form of a U-turn, S-turn, or a complete circle, as illustrated at *G*, at which point the capillary tube is enlarged; and a supplementary mercury reservoir *H* at the upper end of the tube.

When the thermometer is inverted the extra weight of the mercury in the enlarged section of the capillary tube in the gooseneck breaks the mercury column at the knife-edge; the mercury flows into the supplemental reservoir, and extends into the graduated stem where the temperature is read when held in an inverted position. This type of thermometer contains a large volume of mercury, permitting an expanded scale of graduations, since they are based on the expansion and contraction of the total amount of mercury in the reservoir and capillary tube; but the reading of the scale is based on the amount of mercury above the knife-edge after it flows into the smaller reservoir. This type of thermometer is usually graduated in degrees centigrade, with a range from −2° to +35° C., each degree being subdivided into five parts, although some are only subdivided into half-degrees.

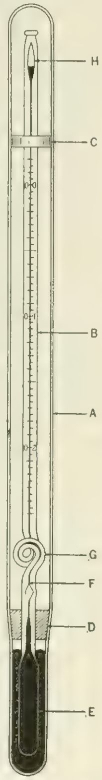

FIGURE 84.—Deep-sea reversing thermometer.

### *4712. Temperature Errors*

Temperatures measured with protected reversing thermometers may contain small errors from two different sources. One of these is an intrinsic error of the thermometer due to slight irregularities in the capillary tube and slight errors in the graduations of the temperature scale. The other error is due to a change in the volume of the mercury contained in the capillary tube and smaller reservoir caused by the different temperature of the surrounding air after the thermometer has been brought to the surface. The temperature in situ may be obtained by correcting the observed temperature for these errors from the report of the calibration test made by the National Bureau of Standards. A copy of this is furnished with every reversing thermometer. This report contains the manufacturer's number, the National Bureau of Standards number, the thermometer scale, the value of each graduation, and in addition, the following type of information in tabular form:

| Temperature when thread is detached | Correction (in degrees) when temperature of detached thread is— | | |
|---|---|---|---|
| | *0° C.* | *15° C.* | *35° C.* |
| 0° C | (+0.12) | −0.49 | −1.30 |
| 15° C | +0.76 | (+0.11) | −0.75 |
| 35° C | +1.76 | +1.07 | (+0.14) |

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The first column may be considered for practical purposes as the observed temperature or temperature at time of thermometer reversal. The entries in the three columns under the second heading are the corrections to be applied (algebraically to the observed temperatures) for three different temperatures of air in the thermometer at the time of reading. The National Bureau of Standards determines, by actual comparisons against the standard, only those corrections shown in parentheses; the other corrections are computed. The coefficient of expansion of the glass and the volume of the supplemental reservoir to the mark at 0° C., which is furnished in the report of the test, are needed to compute these other corrections. The volume is the amount of mercury contained in the supplemental reservoir below the zero graduation and is expressed in the equivalent number of degrees the mercury would occupy in the capillary tube. This is known as the *degree-volume* of the thermometer. Computations involving the above data are not required in the field and are explained only for a better understanding of the National Bureau of Standards report. It is apparent that the magnitude of the corrections in parentheses is an indication of the accuracy of the thermometer. The corrections should be small if the thermometer is accurately graduated and uniform if the size of the capillary tube is uniform. The magnitude of the *computed* corrections varies with the degree-volume of the thermometer and depends on the volume of the supplemental reservoir; if the degree-volume is large, the corrections are large and they will have to be applied to observed temperatures.

### *4713. Corrections to Observed Temperatures*

Thermometer corrections may be conveniently obtained from a graph, as in figure 85, plotted on cross-section paper from the correction values of the National Bureau of Standards report. The temperatures of the enclosed air column when the reversing thermometer is read are plotted as abscissas at convenient divisions of the cross-section paper. The corrections to be applied, minus below and plus above a zero line, are plotted as ordinates. All of the corrections in the report are

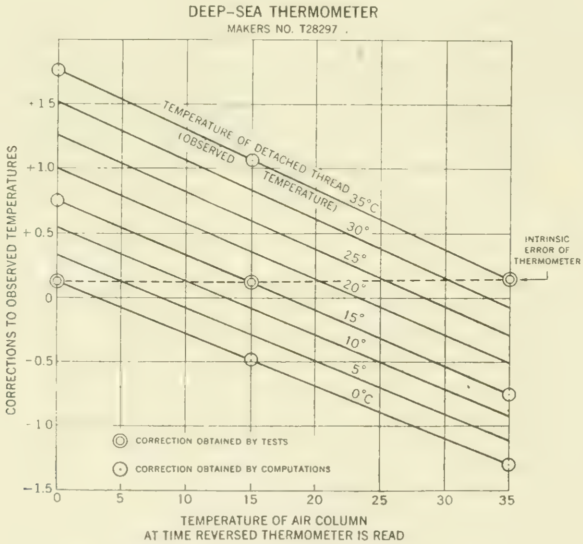


FIGURE 85.—Example of thermometer correction graph.

plotted and the points for each corresponding observed temperature connected. These lines will furnish only corrections for the three observed temperatures tabulated, i. e., 0°, 15°, and 35°. The intermediate lines for each 5° should be interpolated between these by subdivision of the intervening spaces. It is to be noted that the calibration curve of a reversing thermometer retains its shape but shifts slightly along the ordinate as the thermometer ages.

To determine the correction to be applied to an observed temperature, the temperature of the enclosed column of air must be known. This may be determined by several methods. The reading of the thermometer may be deferred until the temperature of the enclosed column reaches the temperature of the atmosphere but this will require from 15 to 20 minutes, depending on the difference in

temperature and the thickness and size of the protecting glass case. The process may be hastened by submerging the reversing thermometer in a bucket of water and allowing the temperature of the column of air to reach the temperature of the water, which will require about 4 or 5 minutes. The temperature of the enclosed column of air is easily determined when a special reversing thermometer, that has an auxiliary thermometer inside the protecting case, is used. With this type it is only necessary to take a simultaneous reading of the reversing thermometer and the auxiliary thermometer. Regardless of the method used to obtain the temperature of the enclosed column of air, the graph (fig. 85), is entered with this temperature on the abscissa scale and where it intersects the temperature of the detached thread (observed temperature) the correction is read from the ordinate scale.

### *4714. Accuracy of Observations*

Precisely measured temperatures are not necessary for hydrographic surveys. An accuracy to a tenth of a degree centigrade is satisfactory for all purposes. This is equivalent to an accuracy of one-half meter per second in the velocity of sound, which is adequate for the computation of the horizontal velocity and for correcting echo soundings. In water of moderate depth (100 fathoms or less) this accuracy may be obtained if the reversing thermometer is raised rapidly and the temperature read immediately after the thermometer reaches the surface, before sufficient time has elapsed for the temperature of the enclosed column of air to change materially. The observed reading should, however, be corrected for the intrinsic error of the thermometer, which will be obtained from the corrections based on actual tests (not the computed ones) made by the National Bureau of Standards. If the temperature is not read immediately, or if the observations are made in deep water, the temperature of the enclosed column of air should be determined and the total correction made.

Accurate water temperatures are sometimes required for scientific studies but, when required, the Chief of Party will be so notified in the project instructions. For such use additional precautions are necessary to ensure that the temperatures are accurate to a few hundredths of a degree centigrade. A special reversing thermometer, graduated to tenths of a degree and containing an auxiliary thermometer, should be used when accurate temperatures are specified.

### *4715. Unprotected Reversing Thermometer*

There are also deep-sea reversing thermometers of an unprotected type, which are not sealed in glass cases to protect them from the pressure of the water. These are not used by the Coast and Geodetic Survey, but are sometimes used in oceanographic studies. An unprotected reversing thermometer will give a fictitious temperature higher than the true temperature because of the compression of the glass. Used in combination with a protected reversing thermometer at the same depth, the difference in temperature of the two is a measure of the pressure, and from these data the depth at which the thermometers were reversed may be computed. This method is used to determine the depths at which observations are made, especially during rough weather when the sounding wire does not remain vertical.

### *4716. Insulated Water Bottle*

Water temperatures may also be measured with an ordinary type of accurately graduated thermometer enclosed in an insulated container such as the Nansen-Pettersson water bottle. The container is made of metal with interior insulation. It has an upper and a lower valve which remain open during the descent of the bottle, but which are closed at the desired depth by means of springs, released by a messenger. The ther-

mometer is enclosed and sheathed in strong glass with the mercury reservoir of the thermometer projecting into a cylinder containing the water sample and the graduated stem extending upward into a tube at the top of the container, where it may be read. The insulated water bottle can be used only to a depth of about 300 fathoms and temperatures obtained in this way must be corrected for a small decrease in temperature caused by the decompression of the water sample and bottle. Its advantage lies in the fact that the temperature and water sample are obtained simultaneously with one instrument.

### 472. Reversing Thermometer Frames

A necessary adjunct to a deep-sea reversing thermometer is a frame which protects the thermometer, and by which it may be capsized at any desired depth by means of

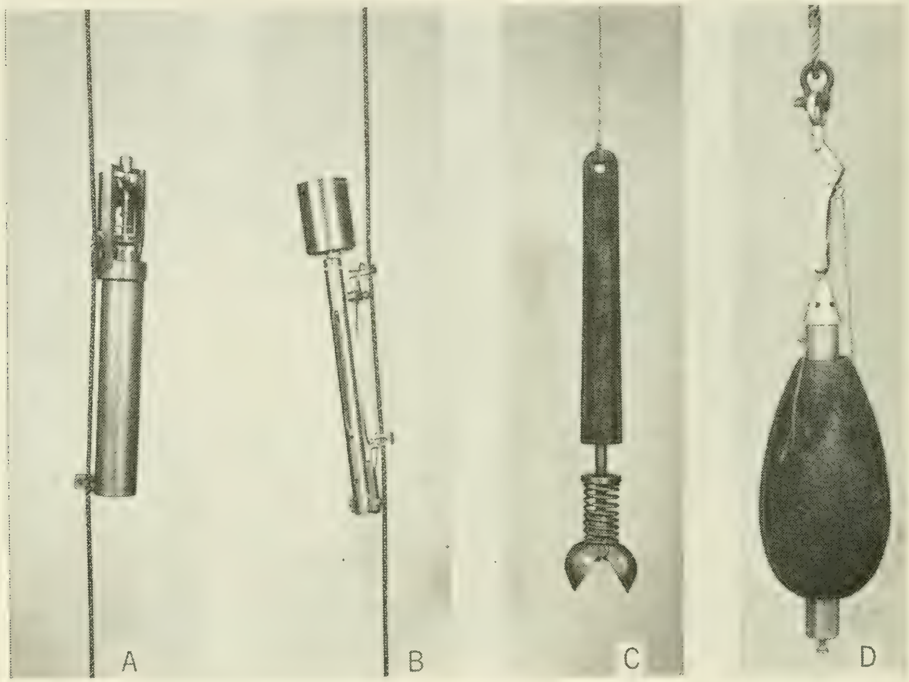


FIGURE 86.—Oceanographic instruments in position to sound. *A*. Improved Sigsbee watercup. *B*. Tanner-Sigsbee reversing frame and reversing thermometer. *C*. Sounding lead with snapper type of sampling device attached. *D*. Belknap-Sigsbee specimen cylinder with sounding weight attached.

certain mechanical attachments. Some frames are capsized by a messenger which trips the inverting mechanism, and others utilize a propeller which revolves as the instrument is drawn upward through the water, withdrawing a pin that allows the thermometer to capsize. Some reversing frames are incorporated in instruments used to obtain water samples (see **474**), but the frame generally used by the Coast and Geodetic Survey is designed exclusively for inverting the deep-sea thermometer. It is known as the Tanner-Sigsbee reversing frame.

### *4721. Tanner-Sigsbee Reversing Frame*

The Tanner-Sigsbee reversing frame (*B* in figs. 86 and 87) is designed for only one thermometer, which is held in a slotted metal tube holder by means of two helical springs one at each end of the tube. The springs press against rubber cushions in which the ends of the thermometer rest. The lower end of the holder is hinged to the bottom of the frame, the upper end being held in place by a pin. The pin is the lower end of a coarse-threaded shaft to the top of which a propeller is attached. The blades of the propeller are arranged so that downward passage through the water forces the pin into the small hole in the top of the holder, maintaining it upright, but as soon as the frame

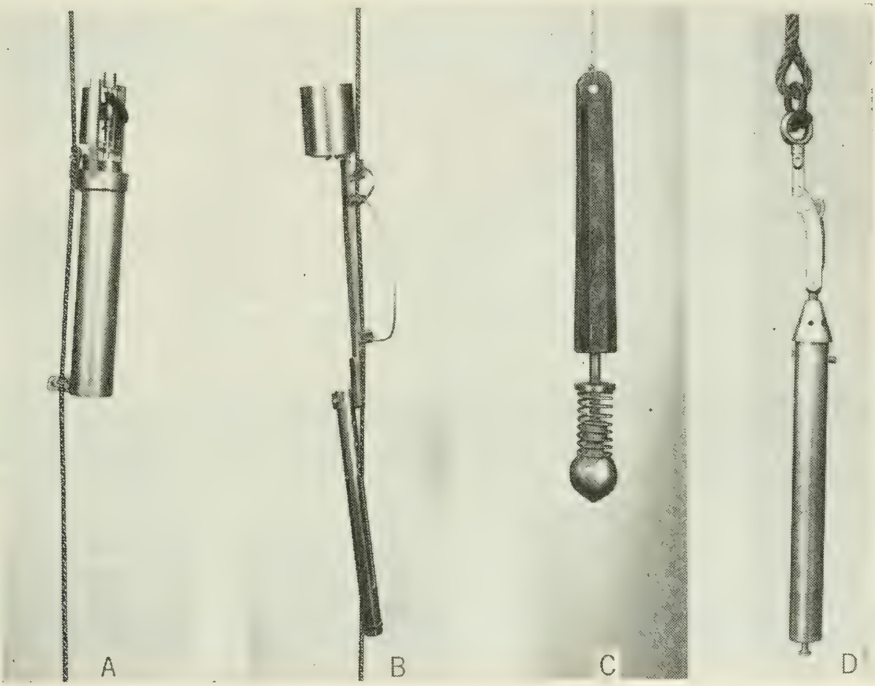


FIGURE 87.—Same oceanographic instruments after sounding.

is drawn upward, the propeller revolves withdrawing the pin from the hole so that the holder is free to capsize. The pitch of the propeller is large enough so that raising it through less than 6 feet of water will withdraw the pin. The frame is clamped at top and bottom to the sounding line by a long spring.

To assemble the reversing frame for use, the top of the holder is unscrewed and the upper spring and rubber cushion are removed from the thermometer holder; the reversing thermometer is inserted in the holder with the large mercury reservoir towards the hinged end and turned so that the graduated scale will be visible through the long slot in the holder. The top spring is replaced with the rubber cushion against the thermometer and compressed while the top is screwed to the holder. The holder is secured in an upright position by revolving the propeller until the pin engages the hole. The frame is now ready to be clamped to the sounding line. The propeller end of the frame must be uppermost when it is lowered into the water. Since the clamp is likely to slip on sounding wire, a short section of leadline material, to which the frame may be clamped, must be inserted between the wire and the sounding lead. The reversing frame must be attached to the sounding line high enough above other instruments so that the thermometer holder will not strike them when it is inverted.

The Tanner-Sigsbee reversing frame has been improved in recent years; the propeller is now built with three blades and with an increased pitch. The improved models are faster-acting and have been observed to capsize the thermometer when raised through only 1 foot of water. The propeller shaft must be thoroughly oiled and maintained in good condition in order to retain this rapid action.

Certain difficulties may be experienced in operation. When the thermometer holder fails to capsize it is probably due to improper adjustment of the propeller blades. One of the blades of the propeller is slightly wider than the other two and is adjusted to strike a stop pin when the instrument is lowered, to prevent the propeller screw from jamming against the threads. The stop pin must have a flat top and project just enough so that the propeller blade will not touch it at all on the revolution just preceding that when it strikes the pin and stops. If readjustment is necessary in the field the pin should be filed to a flat end of the required length.

Another possible difficulty is that the long spring clamp may lose its tension which will permit the frame to slip on the sounding line. The spring is made of bronze to resist corrosion, but it does not have much tension. The tension may be increased by pulling the long part of the spring away from the frame. Serving the sounding line with sail twine to provide a larger diameter for the two clamps will prevent the frame from slipping; or better still, the frame itself may be lashed to the sounding line with sail twine.

### *4722. Other Reversing Thermometer Frames*

Another reversing frame of modified design operates on the same principle as the Tanner-Sigsbee reversing frame. This instrument also utilizes a propeller but it contains two thermometer holders—one for a protected and the other for an unprotected thermometer. The holders are pivoted near the center between two vertical members of the frame, and when released by the action of the propeller, they are inverted by a weight attached to the upper end. This frame is provided with clamps by which it may be attached to the small-diameter sounding wire.

The Knudsen type of reversing frame is constructed exactly like the one described in the preceding paragraph, except that the mechanism is actuated by a messenger (see **4742**) that releases a spring trigger which permits the thermometers to capsize. The messenger type of release is more positive acting than the propeller type. With it the reversal occurs with certainty at the desired depth, while the propeller type may be reversed prematurely in a rough sea by the rolling or pitching of the vessel raising the instrument through the water sufficiently to revolve the propeller.

These two types of reversing frames are not used by the Coast and Geodetic Survey.

## 473. BATHYTHERMOGRAPH

The bathythermograph is a device for obtaining a continuous graphic temperature-depth record of sea water. With it temperatures can be measured rapidly, and better information can be obtained on the vertical distribution of temperatures. The instrument is new and should be considered in the development stage, but it certainly embodies desirable features that simplify the problem of determining the changeable temperatures of the upper layers of water adequately for use in hydrographic surveying, particularly where these data are needed for the computation of the velocity of sound.

There are two types of bathythermographs, the bimetallic-reed and the Bourdon, differing only in the device employed to measure the temperature and in the construction necessary to accommodate this device. Both measure temperatures between 0° and 30° C.

### *4731. Bimetallic-Reed Type Bathythermograph*

The first model of the bathythermograph contained a bimetallic-reed temperature element enclosed in a metal tube 2½ inches in diameter and 27 inches long. The upper part of the metal tube had perforated sides to permit the free passage of sea water. The reed was attached through heat-insulating material to a pressure element in the lower watertight compartment of the tube. The pressure element consisted of a series of metallic bellows that compressed with an increase in pressure, moving the bimetallic reed longitudinally in the tube. Variations in temperature bent the bimetallic reed to move a stylus attached to its upper end which was in contact with a stationary glass slide. The contact side of the slide was smoked by a special process, and on it a curve of temperature correlated with depth was traced by the action of the bending of the bimetallic reed and the compression of the pressure element.

The bimetallic-reed type of bathythermograph makes a record of the temperature during its descent through the water and another during its ascent. The trace on the smoked glass is likely to be rather wide when used during rough weather, because of excessive vibration in the bimetallic reed. This model can be used to a depth of 82 fathoms but the vessel must be stationary in the water and, because of instrumental lag, the speed of lowering and raising must not exceed 10 fathoms per minute in order to avoid a double trace.

### *4732. Bourdon Type Bathythermograph*

The new design of the bathythermograph (fig. 88) incorporates a Bourdon type of temperature element, eliminating many of the objectionable features of the bimetallic-reed type. The size is about the same and the pressure element is essentially the same but is located in the upper part of the metal tube. The glass slide, on which the record is traced, is attached to the lower end of the pressure element

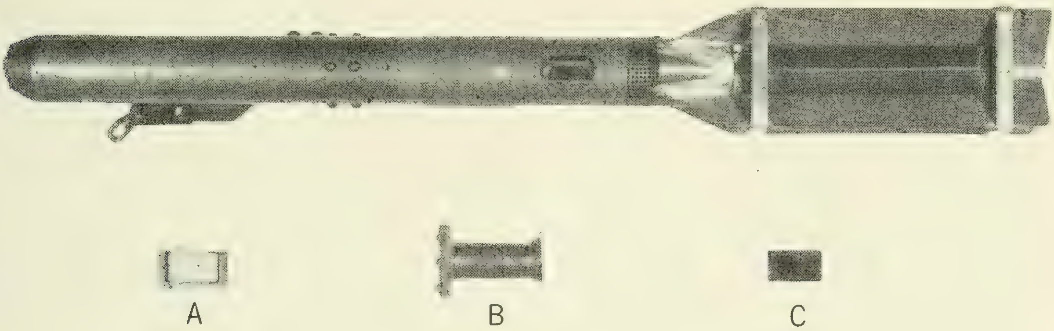


FIGURE 88.—Bourdon type bathythermograph. *A.* Graduated grid. *B.* Scanning device. *C.* Smoked slide.

and is moved longitudinally along the axis of the instrument by changes in pressure. The spiral of the temperature element is mounted inside the lower end of the tube in a square housing, only the bulb of the temperature-responsive system being outside in full contact with the surrounding water. A stylus arm is attached to the Bourdon spiral, the stylus marking the temperature-depth curve on the smoked slide.

The Bourdon type of bathythermograph is more sensitive to temperature changes and less sensitive to vibrations, and it may be lowered and raised faster than the bimetallic-reed type. Its use is limited to depths less than 75 fathoms. With it a temperature trace may be obtained from a vessel while underway and satisfactory results have been obtained at a speed of 15 knots. For use while underway, a considerable length of wire and an additional weight are necessary to permit the instrument to reach the maximum depth. When the bathythermograph is used from a vessel stationary in the water, the record of both traces is valuable as a check and to ensure that the instrument is working correctly. However, when the instrument is used while underway the two curves may not coin-

cide because the paths of descent and ascent will be at different places, and the temperatures at equal depths may differ. The Bourdon type of bathythermograph may be provided with a Nansen bottle clamp, which contains a mechanism that can be tripped by a messenger to raise the stylus from the glass slide when the instrument reaches its lowest point of descent. This eliminates any temperature trace being made during ascent.

### *4733. Projector and Slides*

The glass slides are very small, 1 by $1^{21}\!/_{32}$ inches, and the temperature trace must be enlarged at least four times for satisfactory use (see *C* in fig. 88).

A special projector is used to throw an enlarged image of the trace on a ground-glass screen where it may be traced with pencil or pen on a translucent calibration graph. The slide holder in the projector is constructed to hold the glass slide in the same relative position it is held in the bathythermograph and no reference marks are needed on the slide. The special projector is expensive and is not essential, for the slides may be projected in any 35 mm commercial enlarging camera with a good lens, obtainable from any camera supply store. When the latter is used the slides have to be projected on a calibration graph, where the temperature trace is adjusted to thermometer temperatures plotted thereon as reference points. These thermometer temperatures are taken by reversing thermometer, simultaneously with the bathythermograph measurement.

A calibration graph must be constructed for each bathythermograph from a complete series of simultaneous observations with the instrument and a reversing thermometer. The depths are plotted as ordinates and the temperatures as abscissas. The graph consists of a system of vertical parallel lines crossed by a system of curved lines with a radius equal to the length of the stylus arm connected to the temperature element (in the Bourdon type), or the length of the bimetallic reed (in the bimetallic-reed type), multiplied by the number of times the trace is to be enlarged. An arbitrary spacing between the curves is chosen such that the graph will cover the maximum depth range of the instrument. The spacing of the vertical lines is determined by projecting on the graph the various slides for which the ranges of temperature have been accurately obtained from simultaneous observations. The distances on the graph for various temperature differences resulting from the comparisons are then averaged and the correct spacing determined for degree intervals. The abscissas of the graph are made for the range of temperature of the instrument. A suitable size calibration graph may be made on 8- by 10½-inch paper to provide for enlarging the trace eight times when projected. After the calibration graph has been constructed by the field party it may be sent to the Washington Office for reproduction (see **482**).

After calibration, a simultaneous thermometer temperature at the surface and a depth measurement of the lowest part of the temperature trace suffice theoretically to correlate the temperature trace to the calibration graph. Practically, additional simultaneous thermometer temperatures are needed near the midpoint and lowest part of the trace.

A box containing 100 glass slides is furnished with each bathythermograph. The slides are made of noncorrosive glass, smoked on one side by a special process. After a slide has been used and the temperature trace has been permanently recorded on the calibration graph, the smoked coating may be removed and renewed for use a second time. The slide should be thoroughly cleaned in a bath of carbon tetrachloride, or a similar liquid, to dissolve the thin film of oil which is the base to which the smoke adheres while it is submerged in water. After the slide has been cleaned it should be wiped dry with a clean cloth. Rendered skunk oil is the base for the smoked coating and should be applied with the finger in a very thin uniform coat on one side of the slide. Skunk oil is not readily obtainable at all places but it may generally be purchased at old established pharmaceutical companies in large cities. When it is not available a thin coating of vaseline or petroleum jelly may be substituted. The slides are smoked best over a coal gas flame to obtain a light coating of carbon particles, but this type of flame is not usually available on board ship. The best substitute is cigarette lighter fluid in an alcohol wick lamp. The glass slide is held over the flame, oil-coated side down, and the oil baked until its glossiness has disappeared and the entire surface of the slide has a dull appearance. A piece of wire may be bent into a shape to hold the glass slides over the flame. They should not be held over it too long because the glass may crack if it is overheated.

## 474. WATER SPECIMEN CUPS

Water specimen cups are designed to trap samples of sea water at desired depths so they may be brought to the surface for examination. Various types of cups have been designed for this purpose, among which may be mentioned the Ekman and Nansen reversing water bottle; the Meteor, Allen, and Nansen-Knudsen closing bottle; the Nansen-Pettersson insulated bottle (see **4716**); the Sigsbee watercup; and the Green-Bigelow closing bottle. Only the last two of the types listed are used by the Coast and Geodetic Survey at the present time.

### *4741. Sigsbee Watercup*

The Sigsbee watercup (*A* in figs. 86 and 87) is an efficient instrument for collecting water samples. It is similar to the Tanner-Sigsbee reversing thermometer frame (see **4721**) in the way it is attached to the sounding line and in that a propeller is employed to hold the valves closed. There are two poppet valves on the Sigsbee watercup, one at the top and one at the bottom, which are connected by a rod through the axis of the cylinder so that the two valves open and close simultaneously. The propeller is mounted in a frame at the top of the cylinder and revolves freely on the descent, but on the ascent a clutch engages a locking screw pin so that the revolutions force it down against the upper valve. The valves remain open while the instrument descends, they close when it is motionless, but on the ascent they seat firmly and the action of the propeller locks them in this position. When the watercup is hoisted to the rail of the ship, the locking device is first unscrewed, then the upper valve is raised with the fingers, allowing the water to flow from the watercup into a hydrometer jar held under the lower valve. Like the Tanner-Sigsbee reversing frame, the Sigsbee watercup is designed to clamp on leadline or similar light line and must be placed so that the propeller is at the top.

### *4742. Green-Bigelow Water Bottle*

Although seldom used by the Coast and Geodetic Survey, the Green-Bigelow water bottle is an efficient instrument which has the additional advantage of embodying a reversing thermometer holder. The water cylinder is hinged on one side of a heavy frame, the hinges incorporating stopcocks at the upper and lower ends of the cylinder. A reversing thermometer holder is pivoted on the frame so that it will capsize when released. A mechanism is provided to hold the stopcocks of the water cylinder open and the thermometer holder upright while the instrument is lowered. When the desired depth is reached, a messenger, that fits around the sounding wire, is released at the surface and descends along the wire until it strikes a trigger on top of the instrument. This releases the reversing thermometer holder and allows the water cylinder to fall on its hinges, closing the stopcocks. The water cylinder contains a petcock through which the water sample may be drawn off into a hydrometer jar.

### *4743. Multiple Sea Sampler*

The multiple sea sampler is a new instrument that promises to be a valuable accessory in oceanographic surveys. It comprises six sample bottles arranged so that they trip and take water samples at different selected depths from a vessel underway. It is limited in use to depths less than 82 fathoms.

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The sample bottles are placed in a frame around a central column containing a pressure element similar to that in the bathythermograph. Each bottle has two stopcocks, one at top and bottom, which are operated simultaneously. In the upper part of the pressure element are six slots, one opposite each bottle, which can be adjusted in length to correspond to different depths. When the bottles are in place around the central column the stopcocks are held open by triggers pressing against the upper part of the pressure element. As the instrument is lowered through the water, the pressure element contracts and each trigger in turn can enter its respective slot, releasing the stopcocks which are closed by spring action. Thus, each water bottle in turn is closed at a depth corresponding to the pressure for which the length of the slot is adjusted.

### *4744. Bottom Specimen Cup*

The Belknap-Sigsbee specimen cylinder, commonly known as a detaching rod (*D* in figs. 86 and 87), contains a device to obtain a sample of soft bottom and of the water at the bottom, but its principal use is to release a sinker when the instrument strikes the bottom. Only when the bottom is soft or oozy will a sample of the bottom be obtained, and even in this case it may be mixed with the water.

The water specimen cylinder has a poppet valve on its lower end which is held open by the force of the water during descent but closes as soon as it is raised off the bottom. During the descent water flows freely through the valve and through holes in the top of the cylinder, both of which are closed on the ascent. The action of the poppet valve is often ineffective as some of the bottom material frequently prevents the valve from closing tightly and the water sample is lost, but in this case a sample of the bottom material is usually obtained. The most effective instrument for obtaining samples of bottom water, satisfactory for hydrographic purposes, is a Sigsbee watercup attached to the sounding line a few fathoms above the bottom (see **4741**).

The sounding weights used with the Belknap-Sigsbee specimen cylinder are specially cast pear-shaped weights with a vertical hole through which the cylinder passes to make contact with the bottom. The weights are cast with heavy wire loops on opposite sides by which they are suspended from a trigger at the top of the instrument by a seizing wire sling. This trigger is known as the Sigsbee releasing device and detaches the weight when bottom is struck. (See also **4665**.)

## 475. HYDROMETER SETS

The method usually used by the Coast and Geodetic Survey to determine the salinity of sea water (see **633**) is to measure the specific gravity of the water with a hydrometer. Salinity and density are related by definition, so that if the relative density or specific gravity is known, the salinity may be found by the use of tables or a graph. By this method the salinity may be determined within one or two units in the third significant figure, if the temperature of the water sample is measured to the nearest 0.1° centigrade and the specific gravity to one in the fourth decimal place. The temperature and specific gravity of a water specimen are measured with a hydrometer set consisting of a hydrometer jar, a laboratory centigrade thermometer, and a set of three hydrometers graduated for different ranges of specific gravity. These are illustrated in figure 89.

There are other instruments used by scientists to measure directly the density of sea water, from which salinity can be obtained; these are not ordinarily used by the Coast and Geodetic Survey. The pycnometer gives very accurate results, but it

cannot be used on board ship, since it involves a balance; neither can the method of hydrostatic weighing, a modification of Mohr's balance, for the same reason. The Nansen total immersion hydrometer gives very accurate results but the method is laborious, and requires considerable time for a determination and relative stability of the vessel. The Pettersson chain hydrometer also requires excessive time but is otherwise well adapted for field measurements. These instruments have another serious disadvantage in that large water samples are required.

### *4751. Hydrometers*

A glass hydrometer has a small graduated stem, and a bulb counterweighted for the range of graduations on the stem. In order to reduce the length of the hydrometer stem for use in a water sample of small quantity, hydrometers are furnished in sets of three, graduated for the following ranges of specific gravity: 0.9960 to 1.0110, 1.0100 to 1.0210, and 1.0200 to 1.0310. This total range is sufficient to include the specific gravity of any sample from fresh water to the most saline likely to be encountered in sea water. The scales of the hydrometers are graduated to 0.0002 of specific gravity and can be estimated to 0.00005. Hydrometers are tested for accuracy by the National Bureau of

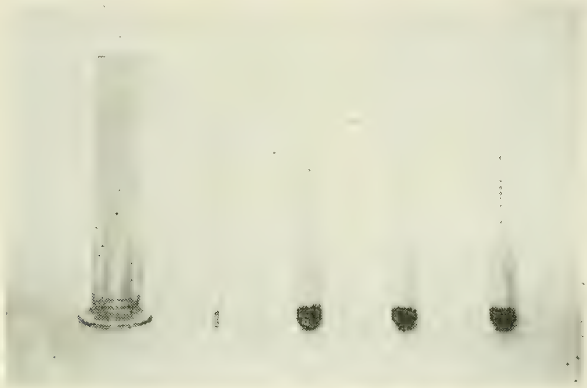

FIGURE 89.—Hydrometer set.

Standards and a calibration table is furnished. A copy of the calibration table is usually sent to the field party when hydrometers are shipped, but if not, it should be requested from the Washington Office. All specific gravity measurements must be corrected for errors of graduation before use in the salinity tables.

The hydrometers used by the Coast and Geodetic Survey are usually graduated to indicate specific gravity at a standard temperature of 15° centigrade, referred to fresh water as unity at a temperature of 4° centigrade. This basis is indicated on the hydrometer by the following inscription: *D.* 15°/4° *C.* The salinity tables have been computed on this basis.

Hydrometers may be graduated on a different basis and there are some in use at present that are graduated on a basis of *D.* 60°/60° *F.* If these are used for specific gravity measurements, the readings must first be corrected to refer them to the basis of *D.* 15°/4° *C.* before the salinity tables are entered (see **6331**). A statement must be made on Form 717, Record of Temperatures, Salinities, and Theoretical Velocities, that the specific gravities recorded have been so corrected. These corrections can be obtained from table 28 of the "Standard Density and Volumetric Tables" (National Bureau of Standards Circular No. 19). For the specific gravity range of sea water encountered in the surveys of the Bureau the correction can be taken as —0.0010. Only hydrometers with manufacturer's numbers from 652 to 976 inclusive are graduated on the basis of *D.* 60°/60° *F.*

Another type of correction must be applied to observed hydrometer readings before the salinity tables are entered, namely, the correction for the variation of the water sample temperature from the standard of 15° *C.* for which the tables are computed. This is described in **6331**.

### *4752. Hydrometer Jar*

The hydrometer jar is a cylindrical glass beaker of sufficient size to contain the water sample and permit immersion of the entire scale of the hydrometer without allowing the hydrometer to touch the sides or bottom of the jar. For use on board ship, a wooden base should be attached to the flanged bottom of the hydrometer jar to decrease the likelihood of its capsizing during rough weather. A 6-inch square piece of heavy wood may be used, to which the hydrometer jar is fastened by means of two straps that fit over opposite sides of the flanged bottom. A disk of sponge rubber, cut slightly larger than the inside diameter of the hydrometer jar and inserted in the bottom, will protect the hydrometer from damage and possible breakage when it is placed in the jar. When the jar is cleaned after use, the sponge rubber should be removed and washed with fresh water and squeezed dry before being replaced in the bottom of the jar. A little fresh water left in the sponge will cause errors in subsequent measurements of specific gravities.

### *4753. Specific Gravity Measurements*

Specific gravity measurements may be made with the hydrometer jar placed on a level bench or shelf, which should be provided on shipboard near the sounding machine, at an appropriate height; or they may be made with the hydrometer jar held in the hand, if there is excessive vibration or rolling. In either case the details of procedure are the same.

A sufficient quantity of the water specimen should be poured into the hydrometer jar to float the hydrometer without touching the bottom, but without overflowing. The hydrometer is placed in the jar and allowed to come to rest. If held in the hand, the jar should be held near the top between the thumb and first or second finger and allowed to swing freely, while the other hand is used to steady the floating hydrometer until just before the reading is made when it must be allowed to float freely. The reading is made at the undersurface of the water (through the glass container and the water), after the outside of the jar has been wiped free of all condensed moisture. With the eye brought nearly level with the water, the surface of the water will be seen as a straight line intersecting the graduations on the hydrometer stem at the specific gravity. These observations should be repeated after disturbing the hydrometer and again allowing it to come to rest.

The specific gravity of a water specimen varies with the temperature of the specimen, and to reduce the apparent (*observed*) specific gravity to the standard for which the salinity tables are computed (see **6331**) the temperature of the water specimen must also be measured. A laboratory centigrade thermometer with a range from 0° to 50°, by which the temperature may be read to tenths of degrees, is provided for this purpose. The thermometer is inserted in the hydrometer jar and temperature readings are taken simultaneously with the hydrometer readings without lifting the thermometer bulb from the water.

Several precautions are necessary during specific gravity measurements. The hydrometer should float freely near the center of the water column, the bulb touching neither the side of the hydrometer jar nor the thermometer. Any small air bubbles clinging to the hydrometer bulb should be detached before the specific gravity is read by rotating the hydrometer or by moving it up and down in the water. If the temperature of the air differs materially from that of the water specimen, the water should be stirred and the temperature of the specimen read before and after the specific gravity measurement, the mean of the two temperatures being recorded.

Some difficulty may be experienced in reading a hydrometer on shipboard, and accurate readings are often impossible when the weather is rough and the ship rolls

excessively. Water samples taken at such times should be preserved in glass bottles, securely sealed to prevent evaporation, and stowed in a dark, cool place until they can be tested under better conditions. The test should not be delayed longer than necessary, because water samples deteriorate with age. Samples need not be retained after the specific gravity has been measured unless they are desired by a scientific organization, in which case the field party will be specially instructed by the Washington Office. The samples, preserved meanwhile as outlined above, should be shipped at the first opportunity.

## 476. Bottom Sample Devices

A device to obtain samples of bottom materials is required so that the bottom characteristics may be shown on the nautical chart. The mariner, and consequently the hydrographer, is interested solely in the material on the surface of the bottom, and only instruments for obtaining this information are needed in hydrographic surveying. (See also **384**.)

The scientist, however, is interested in obtaining a core sample of the layers of bottom sediment. Studies of these core samples disclose a wealth of important scientific data from the 72 percent of the surface of the earth which is covered with water and which, until recently, has remained hidden from the investigator. The additional fact that the approximate limits of the ocean basins are believed to be unchanged since early geologic times also makes studies of these areas of scientific importance. The sedimentary layers have been deposited in historic sequence. In the middle of the ocean basins they remain undisturbed and have been deposited very slowly, so that a vertical core a few feet long represents a very long period of time. The geologist obtains important information from the character and thickness of the successive layers. From core samples an idea may be obtained of variations in the depth of the ocean in the past and also of changes in climatic conditions from a study of the fossils of microscopic animals (Foraminifera). Many minute particles of magnetic materials, that have settled to the bottom, are found in bottom core samples, oriented along the line of magnetic force. A study of these minute particles, with delicate electric apparatus, to determine the shift in orientation through the length of the core, reveals the cyclic change of the lines of magnetic force throughout the period of time represented by the deposits in the core.

Such scientific investigations have no practical value in nautical chart construction and the hydrographer has only an academic interest in them unless he is assigned to special oceanographic surveys, for which special instructions will be issued and, in that case, either he or his colleagues will be thoroughly familiar with the various instruments needed, which can be only briefly described here.

### *4761. Snapper*

With the exception of the armed sounding lead (see **4664**), a snapper-type device (*C* in figs. 86 and 87) is generally used for obtaining samples of the surface layer of the bottom in hydrographic surveys. This type of sampling device is especially useful for obtaining samples in deep water where the bottom material will usually be washed off the armed sounding lead during its ascent through the water. The snapper type of bottom sampler was developed by submarine cable engineers and is sometimes called a "telegraph snapper." It has two clamshell jaws that are held open by an interior trigger, held in place by the pressure of a compressed helical spring around the shank of

the instrument. The trigger is formed of two metal pieces hinged on the inside of each jaw, the end of one containing a filed groove and the other a chisel edge. They fit together when the jaws are open and are arranged so that their point of contact is slightly above the line between the two hinges.

The correct adjustment of the tension of the spring is important and must be reached by trial. When the tension is correct the trigger will always be released when the jaws strike the bottom but they will be held firmly closed together at other times. The tension may be increased or decreased by moving a nut, which compresses the spring, along a screw thread on the shank.

The shank of the sampler extends above the upper end of the spring so that it can be inserted in a sounding lead. A lead weighing 35 pounds or more should be used for deep soundings (see **466**).

This type of bottom sampler occasionally fails to return a sample from sand or rock bottom. If a pebble, shell, or other hard object lodges between the jaws to prevent them from closing firmly, the bottom sample will frequently be washed out during the ascent to the surface. A hard bottom will generally dent the jaws badly so that they must be repaired before subsequent use. The snapper is very effective for returning samples of mud or soft bottom.

Snappers are obtainable in two sizes. The small size has a capacity of about 15 cc, the larger having approximately six times that capacity. The small snapper is regularly carried in stock at the Washington Office and will be found satisfactory for all hydrographic surveys. The large size must be ordered specially from the manufacturer but should not be needed unless large samples of bottom material are required for preservation.

The snapper type of sampler is also adapted for use with a detaching weight of special design. This weight is cast in pear-shaped halves, which are held in a seizing-wire sling attached to a Sigsbee releasing device, similar to that embodied in the Belknap-Sigsbee specimen cylinder (see **4744**). When the snapper strikes the bottom the weight is detached and falls apart, falling clear of the snapper, and is left on the bottom.

### *4762. Coring Instruments*

Coring instruments are designed to obtain samples of sedimentary layers from the bottom of the ocean. To be of value the instrument must return an undisturbed sample with the layers in their true relation to each other from top to bottom.

The usual device for obtaining bottom cores is simply a weighted metal tube with a cutting edge which is driven into the bottom by impact on striking. Detachable weights are used with some of these instruments, but with others fixed weights are used. The latter are difficult, in most cases, to withdraw from the bottom and raise from great depths. Most coring instruments require more powerful sounding machines and stronger wire than are customarily used in hydrographic surveying. The impact type of coring instrument weighs 400 to 500 pounds. The length of the core sample obtained depends on the character of the botton, but cores as long as 18 feet, the maximum length of the coring tube, have been obtained from a soft mud bottom.

### *4763. Vacuum Lead*

A recently developed (1941) coring instrument, known as the "vacuum lead," makes use of hydrostatic pressure to force a tube into the bottom sediment. This instrument consists of a coring tube, 18 feet long, which fits into a hollow cast-iron sphere to which

the lowering line is attached. The air is exhausted from the sphere to form a partial vacuum within the cavity, and when the instrument is lowered, water is allowed to flow into the tube. The sphere is provided with a valve which opens when the cutting edge of the tube strikes bottom, allowing the water in the tube to flow into the sphere. The enormous hydrostatic pressure created forces the tube into the bottom. This type of coring instrument has been successfully used to obtain bottom samples in moderate depths of water, but there is no report yet of its having been tested at great depths.

### *4764. Piggot Gun*

The most successful type of coring instrument for deep-sea samples is the Piggot gun. This instrument uses an explosive charge to drive a metal bit into the bottom at the instant the sharp end of the bit strikes the bottom. The quantity of explosive may be varied for different depths and different types of bottom, to make the full length of the tube penetrate into the bottom, provided it is neither hard nor rocky. It has been used at a maximum depth of 2,800 fathoms in the Bartlett Deep, but its limit is apparently only the greatest depth of the ocean.

In construction, the Piggot gun is simple but ingenious. It consists of five principal parts: a weight or *gun*, a cartridge, firing mechanism, water-exit port, and a tube or *bit*.

The gun is made of cold-rolled steel, 10 inches in diameter and 20 inches long, with a 1-inch eyebolt on top, to which the lowering line is attached. The gun has an opening in the lower end forming a straight smooth bore, slightly larger than 2 inches in diameter to furnish a snug fit (clearance 0.0002 to 0.0005 inch) for the 2-inch diameter cartridge and firing-mechanism housing. It is a muzzle-loading gun and the bore is only deep enough to accommodate the combined lengths of the cartridges and firing-mechanism housing. The lower end of the gun is tapered at 45° to reduce the diameter to 4 inches, at the muzzle. One inch above the end of the muzzle four holes are drilled radially, into one of which a ⅛-inch brass shear pin is fitted to hold the mechanism in the bore until it is sheared by the force of the explosion.

The cartridge is made in three sections, a midsection that contains the explosive charge and a section on each end to seal it watertight. There are three parts to the explosive charge, one of a variable number of pellets of howitzer powder depending on the force required, 2 grams of fine-grained powder to ensure ignition and build up a pressure quickly, and a 30-30 rifle primer centered in the lower end of the cartridge which the firing pin strikes to set off the charge. The upper section of the cartridge contains a rupture disk that seals it against the pressure of the water and ruptures when the explosive charge is ignited. A thin copper disk seals the lower end of the cartridge and covers the primer, but is sufficiently dented, when struck by the firing pin, to set off the primer charge.

The firing mechanism consists of a trigger, a firing pin, and a stiff coil spring housed in a brass casing which is attached to the lower end of the cartridge by a bayonet socket. The trigger is a flat piece of metal that fits into an appropriate horizontal keyway, so located that it will be at the muzzle of the gun when assembled. The outer end of the trigger protrudes beyond the bore of the gun and is beveled, while the inner end is notched to receive the end of the firing pin when cocked. The downward momentum of the gun, after the bit has struck bottom, slides the trigger across in the keyway, releasing the firing pin. The coiled spring then forces the firing pin against the thin copper disk, setting off the primer charge. The trigger is provided with a safety pin which is withdrawn after the instrument is over the side and ready to be lowered.

Between the firing mechanism and the bit, a water-exit port of special design is screwed which allows the water to flow rapidly out of the bit. The high velocity with which the bit is discharged from the gun requires a streamlined exit port of diameter larger than the bit, which also serves to engage a collar stirrup, that fits around the bit, providing a means for extracting the bit from the bottom.

The bit in use in 1940 was a tube 10 feet long and 2¼ inches in diameter, made of alloy steel to give it great strength. The inside of the bit contains four longitudinal lands and the grooves between the lands lead into four outside openings which admit water, which flows to the lower end of the bit to fill the cavity when the bit is withdrawn from the bottom. A brass tube fits inside the bit against the lands. The bottom sample is taken in this brass tube, both tube and sample being removed from the bit after return to the surface. The bottom end of the bit contains a cutting edge attachment, made of hardened tool steel, that fits loosely between the sample tube and bit. This attachment is held in place by two small screws, through slots that provide for a slight vertical movement. When the bit penetrates the bottom the attachment is jammed against it, but when the bit is withdrawn, the attachment opens slightly to allow water to flow out of the grooves.

The assembled Piggot gun is suspended by a cable attached to the top of the gun. The firing mechanism is attached to the lower end of the cartridge and they are both held in the bore of the gun by means of a brass shear pin in one of the four holes provided in the muzzle. The water-exit port, with bit attached, is screwed into the lower end of the firing mechanism. The stirrup is placed on the bit and adjusted so that it hangs near the lower end by a lanyard attached to the sounding cable. When the bit strikes bottom, the weight of the gun operates the mechanism that actuates the trigger to release the firing pin. The exploded charge blows the assembled parts into the bottom, separated from the gun but still attached to the sounding cable by means of the stirrup and lanyard. When the instrument is raised, the collar of the stirrup slides up the bit until it comes in contact with the enlarged diameter of the water-exit port and the bit is withdrawn from the bottom.

## 477. Roberts Radio Current Meter

A radio current meter, designed by an officer of the Bureau, was tried out experimentally in 1940, and in 1942 in a current survey in Puget Sound 12 stations were occupied using 3 of these instruments. At one station a series of 20 days' observations was secured, with the longest break of 8 hours' duration. The breaks in the record were due principally to radio interference and static.

The principle of the instrument is simple: A powerful magnet, pivoted so it is free to aline itself in the magnetic meridian, is mounted in a streamlined casing with fins which cause it to stream with the current at all times. By revolution about an axis concentric with the axis of rotation of the magnet, an electric contact is made successively with one point attached to the magnet and one point on the casing. It is apparent that the *direction* of a current will be indicated by the radial relation of the two contacts in one revolution cycle.

If the electric contact is revolved by the force of the current, the time of revolution is a measure of the *velocity* of the current.

The meter is suspended from a streamlined buoy as described in **2843.** Radio signals are transmitted, when the electric contacts close, by a transmitter similar to that used in Radio Acoustic Ranging (see **6433**, **6513**, and **6523**) which is installed in the buoy. The radio signals are recorded on a chronograph tape, such as is used in R.A.R. (see **673** and **6853**), which is installed ashore or on board the vessel used to service the buoys.

Figure 90 is a simplified sketch illustrating the operating principle of the meter. The oil-filled, streamlined casing *A* has fins to cause it to stream with the current, when suspended freely, and an impeller *B* revolved by the current. The latter transmits its motion to the contacting mechanism in the sealed interior of the casing by a magnetic coupling *C*, so designed as not to affect the magnet. The sketch does not show the forward part of the screw impeller, nor the afterbody of the shell, which contains an expansion chamber to equalize pressures inside and outside.

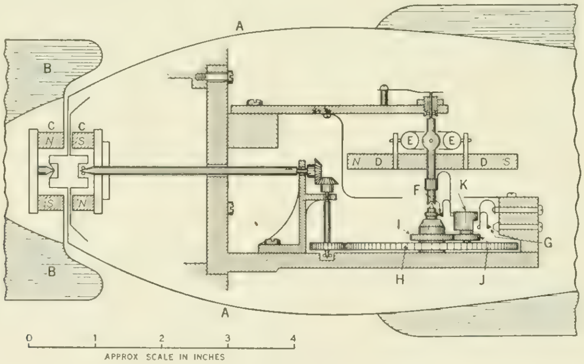


Figure 90.—Radio current meter.

A compass magnet *D*, mounted in gimbals *E* and damped by the oil in the casing, bears a spring-mounted point *F*. Another spring-mounted point *G* is fixed to the frame. By shafts and gears from the magnetic coupling a planetary gear system is revolved at a speed proportional to the velocity of the current. The rotating base gear *H* has mounted on it the planetary gear *J*, which is geared into the fixed pinion *I*. The relationship of the gears is such that the planetary gear *J* rotates about its axis once while it is making two revolutions about the axis of rotation of the magnet.

The upper part *K* of the planetary gear *J* makes the contacts with the points *F* and *G* as it revolves past them. Since *K* is rotating slowly about its axis, its contact with *F* is a rolling contact, which exerts almost no tangential force. This results in little or no effect on the position of the compass magnets, even though a firm contact pressure may be exerted.

The compass magnet and its contact *F* are always alined with the magnetic meridian, and the casing and its contact *G* are oriented with the direction of the current, so the two series of signals have a phase relationship from which the direction of the current can be deduced when they are recorded on a chronograph tape. The two series of signals are identified from the fact that the signals from contact *F* are twice as frequent as those from contact *G*, since contact with *F* is made every revolution but contact with *G* is prevented every alternate revolution by a cut-out segment on one side of *K*.

The casing has trunnions on the sides slightly above the center of gravity, to which a yoke is attached. Where the velocity of the current will not exceed 3 knots, the instrument is simply hung from a buoy by a nonferrous wire with a short length of brass chain to permit it to orient itself freely. Where the velocity of the current exceeds 3 knots, in addition to its suspension, the instrument is connected horizontally to the anchor line by a rigid leader to the trunnions. This leaves it free to swivel vertically on its trunnions and horizontally about the anchor line. So constrained it will not sheer in any current.

The streamlined buoy described in **2843** streams steadily without yawing in a current, and when the current meter is suspended from such a buoy additional accuracy of observations results. The instrument is suspended from the stern of the buoy and its 4-foot separation from the anchor yoke makes fouling extremely rare; and fouling is eliminated entirely by the use of the leader connection to the anchor line.

A radio current buoy can be placed at a station where current data are desired and be left to broadcast its observations. The characteristic signals can be received by a shore or ship radio receiving station anywhere within receptive range and recorded on a chronograph. Or, for comparative purposes, a number of buoys, as many as 10 or 15, can be operated simultaneously at different stations in an area.

In addition to other personnel, operation of the buoys requires the services of a qualified radio technician, and four chronograph observers trained to operate the radio receivers and chronograph, to interpret and scale the chronograph tapes, and to record the results.

### 478. Other Oceanographic Instruments

In addition to those instruments used or adaptable for use in hydrographic surveying, there are other instruments used to collect data and specimens for oceanographic and other studies.

The sea water thermograph is an instrument designed to make a continuous automatic record of surface water temperatures, which data are principally valuable in meteorological studies. The instrument is made with either a bulb-and-capillary or resistance-type temperature element which is inserted into the condenser intake pipe or the keel of a vessel and is connected with a recording mechanism consisting of a clock-driven drum on which a graph paper is placed.

Ocean currents and the circulation of ocean waters are generally studied indirectly by using computed densities, since masses of water moving along more or less well-defined courses tend to retain their physical and chemical properties. If the vertical distribution of temperature and salinity is accurately known at two positions, computations may be made for the various depths from which the velocity and direction of the current may be mapped.

Ocean currents are also studied from direct measurements made with current meters. There are numerous meters suited to various conditions, which record the velocity by either an electric or a photographic mechanism and which utilize various methods to obtain the directions of the current from a magnetic compass needle. Direct current observations are made from vessels anchored at sea in great depths.

Biological studies are made of plankton collected with instruments of three general types. Silk townets for horizontal and vertical tows are generally used to collect specimens. The closing type of townet is devised so that a messenger operates a releasing device which closes the mouth of the net. The use of a closing net improves quantitative determinations. Water bottles of large capacity, similar in construction to those described in **474**, are used to trap a considerable volume of water from which the plankton catch is filtered out after the bottle has been hoisted to the surface. Definite quantitative determinations result from their use, although the catch is very small. The

Pettersson plankton pump contains a small silk net through which water is forced by means of a propeller type of pump. The pump is operated by gravity, a lead weight unreeling a length of cable wound around the propeller shaft. The action of the pump is started by a messenger, a butterfly valve closing the intake when the pump is not in operation.

For deep-sea dredging, special buckets of various sizes are made to be dragged along the bottom to collect samples of the bottom material. The largest dredging buckets are heavy and require special power equipment to raise them from the bottom.

## 48. DRAFTING INSTRUMENTS

Small drafting instruments, the most important of which are shown in figure 91, are an essential part of the equipment of every hydrographic party. Because of their importance both to the hydrographer and to the draftsman, the necessity of taking proper care of them cannot be overemphasized. To use them with maximum speed and accuracy, they must be kept scrupulously clean, free from rust and corrosion, and in the best possible repair.

On board ship small instruments are particularly apt to receive harsh treatment. The rolling of the ship, the salt air, and the fact that different persons must use the same instruments, are contributory to the likelihood of their damage or deterioration. It is not enough to require that everyone using a drafting instrument clean it and replace it in its proper container. Their custody should be entrusted to a responsible officer who should see that instructions for their care are strictly complied with and that they are kept in a locked compartment in the ship's drafting room when not in actual use.

As protection from possible damage when the ship rolls, each instrument should be kept in its separate case, if one is furnished. For small instruments such as ordinary dividers, ruling pens, etc., a cigar box makes an excellent container.

Ruling pens and other instruments in which ink is used should be wiped clean after each use. All drafting instruments should be periodically cleaned to remove rust and corrosion, and a light film of oil should be applied with a soft cloth. Dividers and ruling pens that have become dull should be sharpened on a fine oilstone. When a draftsman at a field office or on board ship needs to use the same instruments for a considerable length of time, they should be issued to him and he should be held reponsible for their care and accountable for damage caused by his neglect.

### 481. DIVIDERS

Dividers are valuable accessories in measuring distances, determining speed, and spacing sounding lines. In the construction and plotting of hydrographic sheets their use is indispensable.

Dividers should be adjusted so that they may be set as desired without undue friction; they should not be so rigid that their manipulation is difficult, nor so loose that they will not retain their setting. The points should be straight and free from burs, and should be kept sharpened to a fine tapering end that will make a small round puncture in the surface of paper.

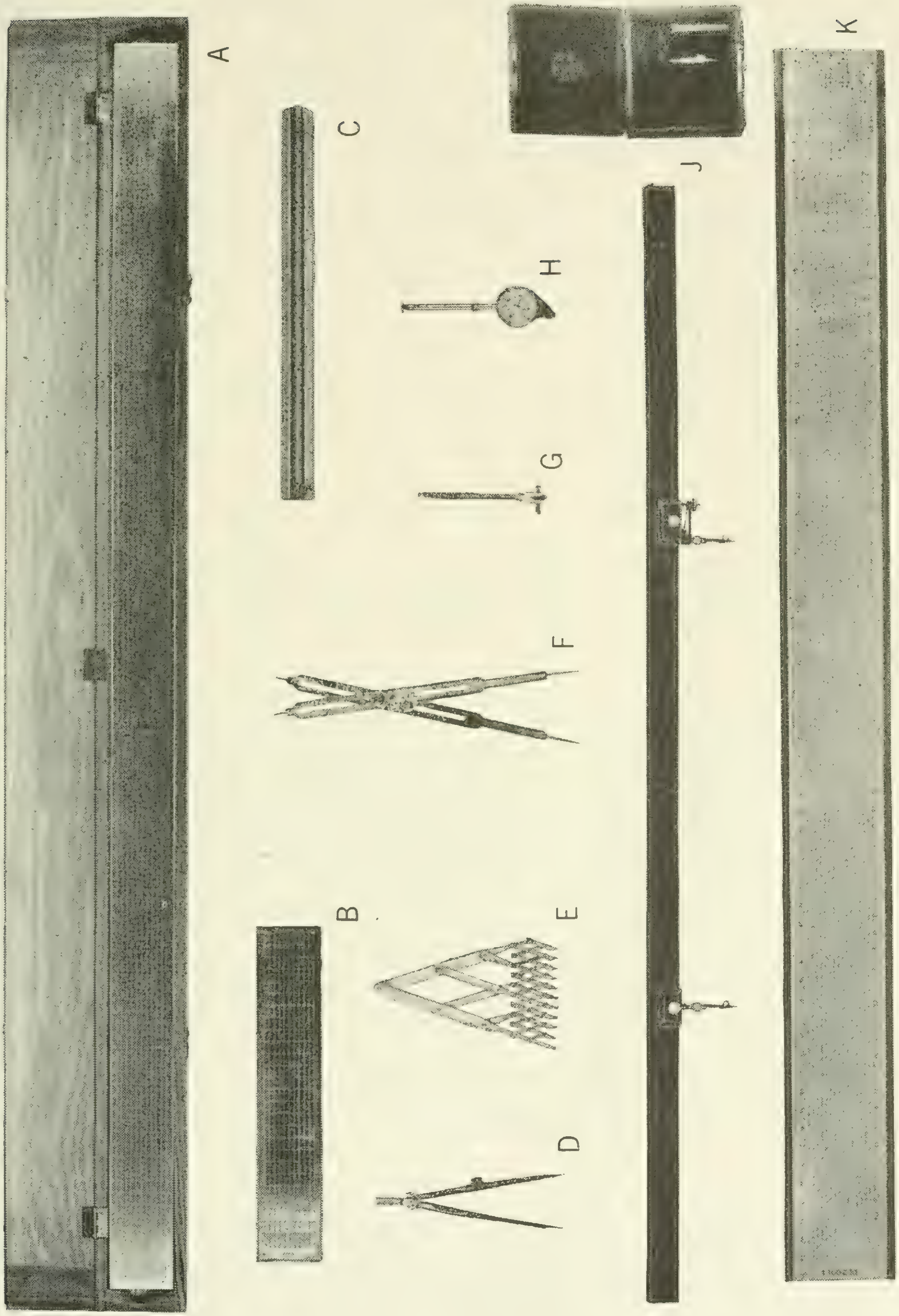


FIGURE 91.—Drafting instruments. *A.* Meter bar. *B.* One-quarter meter scale. *C.* Latitude and longitude scale. *D.* Hairspring dividers. *E.* Spacing dividers. *F.* Proportional dividers. *G.* Opisometer. *H.* Map measure. *J.* Beam compass. *K.* R.A.R. velocity scale.

### *4811. Ordinary Dividers*

The type of ordinary dividers to be used in plotting hydrographic sheets depends on the distance to be measured.

For distances less than about 2 centimeters, the 3½-inch bow-spring dividers are most convenient. This type is constructed from a single piece of spring steel, the ends of which are tapered to form the points. The dividers are sprung so that unscrewing a thumb nut on a threaded spindle connecting the legs increases the distance between the points. The distance is shortened by taking up on the thumb nut. In making large changes in setting, the legs should be compressed with the fingers, while the thumb nut is being set. This ensures minimum wear on the threads and speeds the operation. As the instrument is made of spring steel, the points are fragile and unless used carefully are apt to be broken near the ends.

For measuring distances greater than 2 centimeters, 6-inch hairspring dividers (*D* in fig. 91) are generally used. These are made of two separate legs of stainless steel, held together by a pivot-joint assembly which provides the proper friction for smooth manipulation by means of a small screw and locknut on each side. One leg of the dividers is fitted with a spring and thumbscrew, providing a slow-motion adjustment of about 9 millimeters in setting the distance between the points.

Hairspring dividers are set for the correct friction by skilled instrument makers and it is inadvisable for the field party to attempt adjustments. A special wrench is needed which is not ordinarily available in the field. The use of other tools will usually mar the pivot screws and will seldom accomplish the correct adjustment. When dividers become loose or unserviceable they should be returned to the Washington Office for repairs.

Divider points that have become dull or uneven in length may be sharpened or made even by grinding on a hard oilstone. The points should first be made of even length by placing the legs together and grinding them lightly back and forth against the oilstone, while holding the dividers vertically. Each point should then be sharpened by whetting the outside of it back and forth, at the same time giving the leg a rotary motion by turning it with the fingers. The inside of the leg should remain flat and should not be ground. Neither should any part of the outside of the point be ground so that a flat surface will result. When the shape of the point is nearly correct, great care is necessary to avoid shortening the length of the leg. Dividers with points that are bent or badly damaged should be returned to the Washington Office.

The hydrographer should take special steps to protect his dividers. They should never be used for such purposes as removing corks from bottles or for marking celluloid or metal. Dividers should always be secured on a plotting table on board vessels, especially launches, so they cannot roll off the table. The points of dividers may be protected by sticking them into a small piece of soft rubber eraser, or cork; this is also advisable when carrying dividers in the pocket.

### *4812. Proportional Dividers*

Proportional dividers (*F* in fig. 91) are instruments used chiefly to transfer details between sheets of different scales. They consist of two legs of equal length, pointed at each end and held together by a movable pivot. By varying the position of the pivot, the lengths of the legs on opposite sides of the pivot may be adjusted so that the ratio between them is equal to the ratio between the scales of the two sheets.

Hence, a distance spanned by the points of one set of legs has the same relation to the distance spanned by the points of the other set as the scale of one sheet has to the scale of the other sheet.

A thumb nut moves the pivot in a rack-and-gear arrangement. When the desired setting is reached, a thumb-nut clamp on the opposite side of the instrument locks the pivot in place. A scale and vernier are provided on one leg to facilitate accurate setting. The dividers may be set by reference to the table of settings which is furnished with each pair; they will accommodate varying ranges of scales up to 1 to 11.5.

For use on hydrographic sheets the dividers must be set by test to the exact ratio. The table of settings may be used for an approximate setting but further adjustments will usually be found necessary to take into account distortion in the sheets. The correct adjustment is usually reached by trial and error between corresponding projection lines on the two sheets. When the correct setting has been obtained it should be read from the scale and recorded for future use.

The points of the dividers are of hardened steel and if handled carefully will retain their sharpness during long use. If damaged they may be sharpened and adjusted without affecting the accuracy of the instrument, but the table of settings will no longer be exact.

### *4813. Spacing Dividers*

Spacing dividers (*E* in fig. 91) are specially constructed with multiple legs arranged so as to subdivide the total distance spanned into a number of equal parts and are used by the Coast and Geodetic Survey particularly for spacing soundings between positions on the smooth sheet. The size most frequently used is about 6 inches long and contains 11 points numbered consecutively from 0 to 10. With these dividers distances up to 9 inches may be divided into 10 equal intervals.

Spacing dividers should not be handled roughly and particular care must be taken to ensure that the points are not injured or bent. Should the pivot become too loose or too tight the instrument should be returned to the Washington Office for repairs.

To plot equally spaced soundings on the hydrographic sheet, the space between successive positions is subdivided by placing the zero point of the dividers on the first plotted position and the numbered point corresponding to the number of intervals desired on the next position. The sheet is touched lightly with pencil at each intermediate point to indicate the position of each sounding.

If the smallest interval obtainable with the dividers is greater than the distance between adjacent soundings, the positions of every second or third sounding may be located with the dividers and those of the intermediate soundings estimated.

Where soundings are not equally spaced or where positions are not obtained exactly on the minute, the dividers should be set to account for the elapsed time between positions rather than for the number of soundings. The soundings may then be plotted by the time interval from the first position.

For example, if a position was taken at 9:01 and the next at 9:05½, the elapsed time of 4½ minutes should be set on the dividers by placing the point numbered zero on the first plotted position and adjusting the dividers until the second plotted position falls halfway between points 4 and 5. If soundings were taken at 9:02, 9:03, and 9:04, the divider points numbered 1, 2, and 3 will indicate their positions. If a sounding was at 9:04:15, a dot placed at one-fourth the space between points 3 and 4 will indicate the correct location of the sounding. If a position was taken on a half-minute and soundings were taken on whole minutes thereafter, the dividers are first spaced as above to account for the elapsed time between positions, then moved back one-half space so that point number 1 on the dividers will indicate the position of the first sounding. If the scale of the sheet is large and a 1-minute interval is too long to be spanned by adjacent points, the dividers may be set to intervals of 30 seconds or 15 seconds and the same general method used.

Spacing dividers may be used to obtain quickly and accurately a vessel's rate of speed. Knowing the elapsed time between positions, the dividers are set to indicate minute intervals as described above. On a nautical mile scale constructed for the scale of the sheet, the distance spanned between the zero point of the dividers and point number 6 will give the distance traveled in 6 minutes. This distance multiplied by 10 will give the speed of the vessel in knots.

### *4814. Beam Compass*

The beam compass (*J* in fig. 91) is used to measure distances that are too long to be measured accurately with ordinary dividers. It is indispensable in making projections in the field and in swinging distance circles and arcs in R.A.R. plotting. A beam compass with a short bar is often convenient for use in plotting geographic positions by latitude and longitude (see **7411**).

The beam compass consists of a light, inflexible bar of wood, or metal, and two compass fixtures which slide on the bar and may be clamped at any desired points. The usual beam compass fixtures are made for use with wooden bars. Special fixtures are made to fit tubular metal bars.

It is important that beam compass bars be rigid. They should be made of hardwood and the cross-section shape should be designed to give maximum rigidity. A bar with a T cross section is recommended. Bars are obtainable in lengths from 24 to 60 inches, in multiples of 6 inches. Extra long bars can be furnished for special purposes. (See **3741**.)

Beam compass fixtures are constructed of metal and are designed to slide along the bar guided by the small lip on its edge. A thumbscrew on the side of the fixture working against a small bearing plate provides the means for keeping the fixture alined on the bar and for clamping it in place. Each fixture is provided with a socket into which may be fitted a needle point, pencil point, or ruling pen. One fixture of each pair is fitted with a screw device which works against a spring, providing the point with a slow motion parallel to the bar.

It will be found convenient to assemble the fixtures on the bar so that the thumb screw on the clamping device of each fixture is toward the user, with the slow-motion fixture to the right. In use, the fixture with the fixed point should be kept clamped on the bar while the slow-motion fixture is moved until it is at the approximate distance, where it is clamped. The final adjustment is then made with the slow-motion thumbscrew. The bar should be held lightly but firmly and no force should be applied that might tend to bend it.

The fixtures are furnished in a felt-lined case and they should be kept in the case when not in use.

## 482. SCALES

Scales used by the Coast and Geodetic Survey for constructing projections and for plotting stations or distances on hydrographic sheets are graduated in the metric system.

The standard scale for these purposes is the meter bar, which is made of German silver and graduated by machine with great precision.

Scales for special purposes may be constructed by the field party or will be furnished by the Washington Office upon requisition. Those prepared in the Office are usually made by photographic reproduction and may be furnished on aluminum or glass; or on plain, transparent, or metal-mounted paper if only for temporary use.

A model for a special-purpose scale to be reproduced at the Washington Office should be prepared with great accuracy by the field party on bleached aluminum, metal-mounted paper, or smooth-sheet paper. As the scale will be reproduced photographically, it is preferable that the model be prepared at an enlarged scale and that the exact size to which it is to be reduced be accurately indicated.

Special-purpose scales may often be used to speed the operations of plotting or scaling and in such cases their use is recommended.

### *4821. Meter Bar*

The meter bar (*A* in fig. 91), so called because its graduated scale is 1 meter in length, is the standard scale for all measurements used in constructing projections, plotting distance circles, or other operations involving comparatively long distances. It is graduated on one side at a scale of 1:10,000, and on the reverse side at a scale of 1:20,000. The bar may be used for other scales by applying a simple ratio to the distance

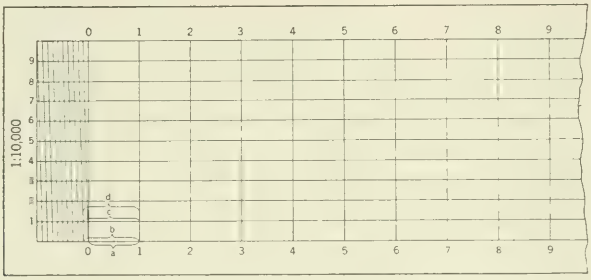


FIGURE 92.—Metric scale. $a$=100.0 meters. $b$=110.0 meters. $c$=111.0 meters. $d$=111.5 meters.

to be scaled. For example, a 10,000-meter distance on a 1:40,000 scale map will equal 5,000 meters on the 1:20,000 scale of the meter bar; or similarly, 2,500 meters on the 1:10,000 scale.

All meter bars now acquired are tested for accuracy and calibrated by the National Bureau of Standards, the allowable error being 0.1 mm for any distance. A copy of the calibration test for a bar will usually be found inside the cover of the box in which the meter bar is furnished. Older bars, for which there are no data as to accuracy, should be carefully verified before use by comparison with a standard of known accuracy.

In addition to the meter bar, quarter-meter scales (*B* in fig. 91) and eighth-meter scales are available. These are not tested for accuracy, and should be compared with a meter bar of known accuracy before use. The quarter-meter scale can also be furnished at scales of 1:8,000 and 1:12,000.

The quarter-meter scale is especially convenient to use for plotting stations or for scaling other comparatively short distances. The eighth-meter scale is furnished as part of the equipment of a planetable alidade and is usually attached to the straightedge of the alidade; separate scales, however, are also available.

*Method of use.*—The length of a meter bar is divided into spaces representing 100 meters each at the scale of the bar (see fig. 92). The width of the bar is divided into 10 equal spaces by numbered parallel lines. At the left end of the bar one 100-meter space is subdivided by 10 parallel diagonal lines in such a way that distances to tenths of a meter may be scaled as illustrated.

In setting a distance on the beam compass or dividers, the point of the leg containing the slow-motion screw should be placed on the appropriate 100-meter vertical division

line at the proper estimated distance above the bottom horizontal line, and the fixed point brought to the approximate setting at the left-hand end of the bar. Holding the fixed point in the left hand the slow-motion screw is moved with the right hand until the fixed point is felt to engage the groove at the correct point. The compass beam or the dividers should always be held parallel to the horizontal lines on the meter bar during a setting.

*Care.*—Meter bars are expensive instruments which should be carefully handled and stored. The finely ruled lines are easily marred by divider points and for this reason particular care should be taken to handle the beam compass or dividers lightly. Bars should be cleaned occasionally with a soft rag and a nonabrasive metal polish. On board ship they should be stored where they will be least exposed to moisture and where they will be secure during periods of rough weather.

### *4822. Latitude and Longitude Scales*

Latitude and longitude scales (*C* in fig. 91) are similar in appearance to triangular engineer scales and are constructed so that any one of the three edges may be placed in close contact with the paper. They are designed particularly for use at scales of either 1:10,000 or 1:20,000 and are not especially useful for other scales. Each rule contains six scales, one for use in plotting latitude, and five for use in plotting longitude at various latitudes. Each scale is slightly longer than 1 minute of arc at a scale of 1:10,000, and is graduated to read to 0.2 second of arc and may be estimated to 0.05 second. Small magnifying glasses are provided which can be attached to the scale and slid along the rule to any desired position.

The scales are designed for plotting or scaling geographic positions by seconds without having to convert the seconds into meters. They are used diagonally across the projection lines and plotting is performed by a proportional process in which any distortion in the paper is automatically compensated for. An experienced operator can use these scales somewhat faster than the beam compass or dividers, but the principal economy in time occurs when distortion in the paper would make an adjustment of the values in meters necessary when plotting with a meter bar. Tests in the Washington Office indicate that geographic positions can be plotted with these scales with approximately the same accuracy as is attained with the beam compass.

Points should be plotted adjacent to the edge of the scale by pricking a small hole in the paper with a fine needle point. Best results are obtained by tilting the needle slightly away from the edge of the scale, so that the needle point and the scale divisions are not obscured by the shaft of the needle.

*Method of use.*—For scaling seconds of latitude of a plotted position, place the scale diagonally across the projection so that the latitude edge bisects the station point, and the 0- and 60-second marks at the ends of the scale coincide with the lower and upper minute lines of latitude. The value in seconds is read directly from the scale. A similar procedure is followed for seconds of longitude, except that the edge bearing the longitude scale corresponding to the latitude of the locality must be used and the ends of the scale, of course, made to coincide with the lines of longitude.

To plot a position it is necessary to plot the correct latitude twice near the meridians east and west of the station, connecting these points with a fine straight line. The value in seconds of longitude is then plotted twice near the adjacent parallels and connected with a line. The correct position is at the intersection of these two lines. Instead of plotting two points for longitude, the scale may be placed diagonally across

the sheet so that the ends of the scale coincide with the minutes of longitude and so adjusted that the scale crosses the latitude line at the correct position for pricking the longitude directly on this line.

### *4823. Lockerbie Diagonal Scale*

The Lockerbie scale is designed for scaling geographic positions in meters from survey sheets or for checking the plotting of stations. It is made by photographic methods in the Washington Office and is provided for a scale of 1:10,000 only. The graduations on the underside of a rectangular piece of thin glass are protected by a thin layer of transparent lacquer. Tests indicate that distances may be measured with this scale with an accuracy of three-quarters of a meter at a scale of 1:10,000.

The scale is divided vertically into 20 equal spaces of 100 meters each by numbered horizontal lines parallel to the bottom edge of the glass. The initial horizontal line is actually omitted, but 0.2 mm above and below its place two horizontal lines are ruled in order that the projection line may be centered between them. The horizontal lines are crossed by 20 vertical lines equally spaced at an arbitrary distance representing a 5-unit interval. Every alternate vertical line is numbered beginning with zero at the left. Each long rectangle formed by adjacent horizontal lines and the outside vertical lines of the scale is accurately divided by a fine diagonal line from the lower left corner to the upper right corner. The diagonal line must be very fine so that it may be placed on and exactly bisect the station dot, when used in scaling. This arrangement of lines serves to subdivide the 100-meter intervals so that, in scaling, distances can be read directly to the nearest 5 meters and may be estimated to the nearest half-meter.

*Method of use.*—The lower edge of the scale is placed against a straightedge near the position to be scaled. Both are moved around on the sheet until the parallel below the position is exactly between the two horizontal lines at the initial of the vertical scale. Holding the straightedge firmly in this position, the scale is slid along it until a diagonal line bisects the position dot. The number of horizontal lines above the projection line gives the *dm.* or latitude distance (see **7411**) to the nearest hundred meters, to which are added the 5-meter intervals, as indicated by the number of vertical lines to the left of the position, the meters and half-meters being estimated from the adjacent vertical lines. In like manner the scale is centered over the meridian and the *dp.* or longitude distance scaled.

The Lockerbie scale is most advantageously used on sheets in which there is no distortion; otherwise the scaled values must be corrected for the distortion (see **7361**).

### *4824. R.A.R. Velocity Scale*

The R.A.R. velocity scale ($K$ in fig. 91) is used to convert time of sound travel in sea water into horizontal distances at the scale of the survey, thus greatly facilitating the plotting of R.A.R. positions. The scale is approximately the same length and width as the meter bar. It is divided from right to left into 50 spaces, each representing the distance traveled by the sound wave in 1 second of time. A subdivided space at the right permits settings to tenths of seconds directly, and to hundredths of seconds by estimation.

From bottom to top the scale is divided by equally spaced horizontal lines, one for each velocity of sound from 1,460 meters per second to 1,540 meters per second at 5-meter intervals. Each of these lines is, in effect, a separate scale. When using a velocity of

even 5 meters, distances are scaled on the appropriate horizontal line; for an intermediate velocity, measurements are made at a proportionate distance between lines.

The scales were formerly inscribed on German silver. They are now made at the Washington Office by a lithographic process on strips of grained aluminum, coated with transparent varnish to protect the markings, and glued to thin wood backs. They are furnished for the same velocity range at scales of 1:40,000, 1:80,000, 1:100,000, and 1:120,000.

For scaling and drawing distance arcs, a beam compass is used, the right-hand fixture of which is fitted with a chisel-edged pencil and the left-hand fixture with a steel point. Distances are scaled horizontally at the point on the vertical scale which represents the velocity of sound in the locality. The steel point should be set on the line representing the whole number of seconds and the pencil point adjusted to the correct distance in tenths and hundredths on the scale at the right.

The lines marking second intervals may be engraved on the scale if desired by using a wedge-point engraving tool guided by a straightedge. This can be done accurately only with care and a steady hand.

### *4825. R.A.R. Chronograph Scale*

The R.A.R. chronograph scale is used to scale to the nearest hundredth of a second the time of an event recorded on the tape of a Gaertner chronograph (**6731**) on which time has been marked in seconds. It is constructed at the Washington Office by photographic methods on plate glass. The lines are on the underside of the glass and are protected by a thin layer of transparent lacquer.

The scale has 11 equally spaced converging lines that divide a distance of about 1.5 cm at the top and about 4 cm at the bottom into 10 equal intervals. The middle line is parallel with the edge of the glass and is about 8 cm long. The converging lines are crossed by six equally spaced parallel horizontal lines perpendicular to the centerline, by use of which the scale is held parallel to the record on the chronograph tape when in use.

### *4826. Graphic Speed Scales*

The rate of speed of a survey vessel, or the distance traveled in a given length of time, may be determined quickly and accurately from a *speed scale*. In hydrographic surveying it is especially useful in small-scale offshore surveys controlled by dead reckoning or R.A.R. The scale may be drawn on a separate sheet of paper or, preferably, on the boat sheet in a space that will not otherwise be used. Two types of speed scales are in general use.

*Construction.*—One type (fig. 93) is constructed for the scale of the boat sheet, principally for use in the field during the progress of the survey. It is usually drawn on the boat sheet with its ordinates and abscissas superposed on the meridian and parallel lines of the projection. It is best adapted for use at comparatively small scales.

To construct this scale, choose a convenient meridian line to represent a speed of 12 knots. Each nautical mile, or minute of latitude, on this line will equal 5 minutes of time. At an arbitrary distance to the right or left choose another meridian line to represent a speed of 6 knots. Each nautical mile on this line will equal 10 minutes of time. The distance between the meridians is subdivided into six equal parts by vertical lines drawn to represent the intermediate speeds between 6 and 12 knots. These are intersected by a series of diagonal lines representing time in minutes, which are drawn to connect the corresponding points on the two meridians first mentioned.

The scale can be extended in either direction to provide for other speeds, or meridians can be first selected to represent other speeds, if the principle of construction described is followed. It is to be noted that the diagonal lines converge at a point representing *zero* speed. It is frequently more convenient to find this point, at a horizontal distance from the first meridian line equal to twice the distance between it and the second meridian, and draw the diagonal lines from it to the points representing intervals of time on the first meridian.

The spaces between the vertical lines representing speeds should be large enough so that tenths of knots may be interpolated by estimation and so that none of the diagonal lines intersects them at too acute an angle.

A second type of speed scale (fig. 94), used principally by verifiers in the Washington Office, is better adapted for use on surveys of larger scales. Its principle is the same, but it is constructed so that the diagonal lines represent the various rates of speed and the horizontal scale may be graduated for use at a number of different scales.

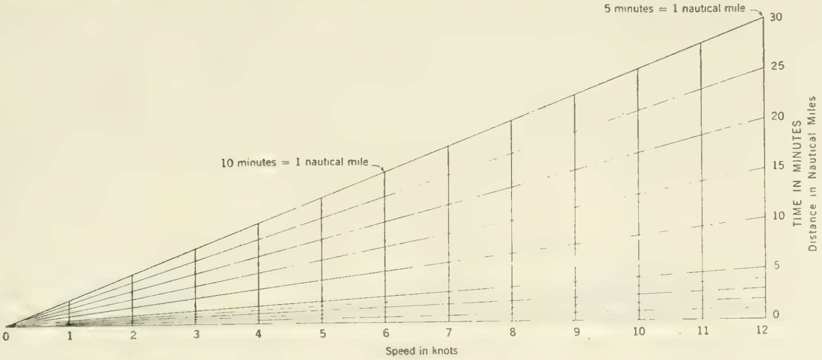


FIGURE 93.—Graphic speed scale for field use.

The scale is a grid on which the spacings along the horizontal axis represent distances in meters, the spacings along the vertical axis represent minutes of time, and the diagonal lines represent speed in knots. Such a scale is constructed for a selected survey scale, e. g., 1:10,000. To construct the grid, lay off along a horizontal line 100-meter distances at the desired scale. At the zero point erect a perpendicular and arbitrarily divide it into equally spaced intervals representing minutes of time. Complete the grid by drawing vertical and horizontal lines through the points of graduation. The minute intervals may be further subdivided for closer determinations.

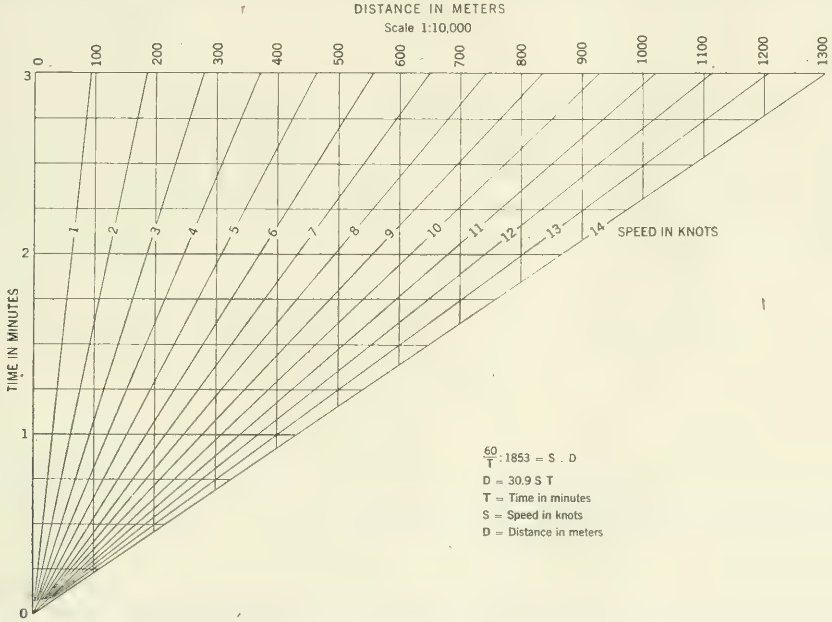


FIGURE 94.—Graphic speed scale for office use.

The diagonal lines may be drawn as follows: Select any speed, e. g., 10 knots. In 3 minutes at 10 knots a vessel travels ½ nautical mile or ½ minute of latitude. In the case illustrated, this is 926.5 meters. From this point on the horizontal line representing 3 minutes, for a scale of 1:10,000, draw a diagonal line to the origin. This diagonal line represents a speed of 10 knots. The positions of other diagonal lines representing other speeds may be similarly determined, or the distance along any horizontal line from the zero vertical line to the diagonal line representing 10 knots may be subdivided into 10 equal parts and these points may be connected with the origin of the scale by diagonal lines, each of which will represent its respective speed.

*Method of use.*—Speed scales of both types are used in the same manner. To find the speed of a vessel the only information required is the elapsed time between two fixed positions and the distance between, which is taken from the boat sheet or smooth sheet by dividers. This distance is applied directly to the speed scale, parallel to the appropriate axis, and the speed to tenths of knots is found by interpolation. The reverse problem, when the speed is known and the time required to cover a given distance is desired, or vice versa, is solved with equal facility. The speed at any moment is obtained from the two preceding plotted positions, and with that speed the moment when the vessel will be at a certain position is easily determined.

### *4827. Log-factor Scale*

The log factor, expressed as a ratio which is the true distance divided by the log distance, may be quickly determined from a log-factor scale, which is simply a proportional diagram constructed for the scale of the survey sheet. This type of scale is used extensively in plotting dead reckoning during hydrographic surveys controlled by R.A.R. or astronomic observations. It is also used in making the dead-reckoning plots used in plotting R.A.R. smooth sheets. (For calibration of logs, see **4454.**)

*Construction.*—To construct a log-factor scale draw two lines at right angles to each other and let the horizontal line represent a log factor of 1.0, the vertical line being merely a construction line. Draw other equally spaced horizontal lines, parallel to the first, to represent the probable range of factors to be used, as in figure 95 from 0.7 to 1.2. The spacing should be sufficient, about three-fourths of an inch, so that hundredths may be easily interpolated. On the horizontal line first drawn, representing a log factor of 1.0 lay off to the right and left of the vertical line distances of 5.5 miles at the scale of the survey. Subdivide the total distance into 11 equal parts, each equal to 1 mile. The upper and lower horizontal lines are similarly subdivided except that the equal intervals are miles multiplied by the respective factors; in the figure each subdivision on the lower line is equal to 1.2 nautical miles and each on the upper is equal to 0.7 nautical mile.

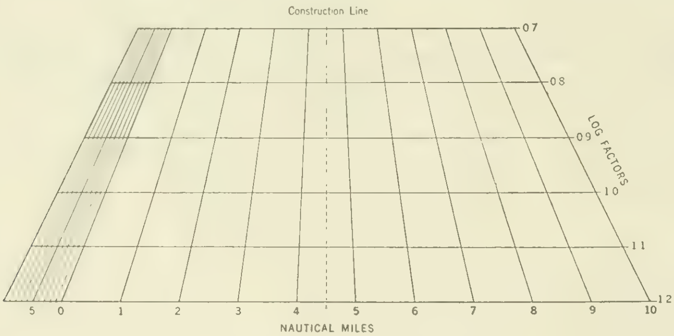


FIGURE 95.—Log-factor scale.

The corresponding points on the upper and lower horizontal lines are connected by diagonal lines which should pass through the corresponding points on the horizontal line representing a 1.0 log factor. Leaving the diagonal line farthest to the left unnumbered, the remaining lines are numbered toward the right from 0 to 10. The interval to the left of the zero line is subdivided into 10 equal parts to represent tenths, and from this hundredths can be interpolated.

The scale is constructed in a fan shape to avoid acute intersections with the horizontal lines.

*Method of use.*—To find the log factor at any time the true distance between two fixed positions is taken off the survey sheet with dividers. This interval on the dividers, held parallel to the horizontal lines, is fitted to the scale where it corresponds to the distance measured by log between the two fixed positions. Where it fits, the log factor is read by interpolating to hundredths. After the log factor is known, log distances may be scaled with dividers from the horizontal scale corresponding to the factor determined, and plotted directly on the survey sheet.

When the speed of the vessel is at a constant rate through the water, time intervals are frequently used for the same purpose as log distances, and a time-distance scale

is needed. It may be constructed to resemble the log-factor scale, except that horizontal distances on the scale represent elapsed intervals of time run, instead of log distances, and the horizontal lines represent various rates of speed, instead of log factors. The rate of speed is determined and distances are taken off the scale in the same manner, except the elapsed time between positions is used instead of the log distances. This time-distance scale is constructed according to the principle used in constructing the first speed scale described in **4826**.

As used in hydrographic surveying, the true distance is the actual distance over the ground, and such a log factor not only takes into account the error of the log but also the effect of current and wind in the direction of progress. Thus the log factor is constantly changing.

### *4828. R.A.R. Plotting Scale*

The R.A.R. plotting scale is a triangular rule about 20 inches long, similar in appearance to an engineer scale. It is graduated in seconds of travel time for a velocity of sound of 1,460 meters per second, and each rule has six graduated edges for the scales of 1:40,000, 1:60,000, 1:80,000, 1:100,000, 1:120,000, and 1:200,000. It is for use in plotting smooth sheets on which distance circles have been drawn, based on a velocity of sound of 1,460 meters per second (see **7341**).

Each second is numbered, except on the 1:200,000 scale where the even seconds only are numbered, and each scale carries two series of numbers starting at zero at opposite ends, so that either end may be used as an initial. Each scale is completely graduated for its entire length. The scale at 1:40,000 has a graduated length of 14 seconds, the smallest division being 0.02 second. The 1:200,000 scale has a length of 70 seconds with a smallest division of 0.1 second. The other scales have proportionate lengths in seconds, their smallest intervals having approximately the same linear length.

To plot an R.A.R. position with the scale the increments or decrements of distance in seconds from the nearest distance circles (see **7631***c*) are plotted normal to the circles. The length of the rule facilitates this. In many cases the rule will extend to the plotted position of the R.A.R. station itself, but where it does not, its length permits alinement by eye accurate enough for all practical purposes.

## 483. MISCELLANEOUS DRAFTING INSTRUMENTS

### *4831. Straightedges*

Straightedges, usually of stainless steel, are available in lengths from 6 to 72 inches. They can be furnished with one edge beveled.

The fiducial edge of a straightedge must be a truly straight line, and tests to verify this should be made prior to use in constructing projections or any operation requiring a straight line. To test a straightedge, two fine dots should be pricked on a thick sheet of paper at a distance apart slightly less than the length of the straightedge. The fiducial edge of the straightedge is accurately centered through these two dots and a fine pencil line is carefully drawn along it with a chisel-edged pencil. The pencil should be held firmly against the edge at a constant angle with the paper. The straightedge is then turned end for end and again centered through the pricked points. If the fiducial edge coincides with the pencil line throughout its length, it is straight, unless it happens to have a symmetrical reverse curve. A magnifying glass will be found helpful in making the test.

Straightedges should be cleaned with soap and water. Abrasive materials should never be used as they tend to scatch the surface and make it more susceptible to the accumulation of dirt.

When not in use a straightedge should be kept in a canvas case or other suitable container and stored in a place where it will be protected from moisture.

### *4832. Opisometer*

The opisometer is a simple instrument designed to measure by revolutions of a small wheel continuous linear distances on a map. In hydrographic surveying it is used principally to measure distances run by the sounding vessel. The main advantages of the opisometer are that distances along curved or irregular lines can be easily measured, and that the total of numerous short distances can be measured without measuring the separate distances.

Two types of opisometers are in use at the present time, both being adaptations of the principle of the odometer, by which horizontal distances on the ground are measured by the revolutions of a wheel equipped with a counter.

The type of opisometer most generally used (*G* in fig. 91) was first made by the Instrument Division of the Coast and Geodetic Survey prior to 1895. It is simply a small wheel, with a knurled rim, that is threaded on a small rod with stops on each end. The wheel is mounted in a fork and held in place by means of the threaded rod along which it moves laterally between stops, when rolled over a surface. One side of the opisometer has a pointer, which extends almost to the outer diameter of the wheel, by which accurate settings are made.

To measure miles of sounding line with the opisometer, the wheel is revolved until it brings up against one of the stops. The pointer of the opisometer is placed over the first position of the line to be measured and the wheel is placed in contact with the paper. The wheel is run along the line, maintaining the same direction of rotation even when turns occur in the line or when the total of a number of unconnected lines is measured. After the total has been traced, the distance is found by running the wheel in reverse along a graduated scale until it is at its original position in the fork; or, on a hydrographic sheet, along a meridian line counting the number of parallels crossed, which will give the distance in nautical miles, the fractional remainder being measured by spacing dividers. In the latter case the distance is reduced to statute miles by multiplying by 1.15, the resulting data being entered in the Sounding Record.

### *4833. Map Measure*

Another and more elaborate opisometer made commercially is known as a map measure (see *H* in fig. 91). Its principle is the same, but it is calibrated and registers distances by a pointer revolving around a dial containing two concentric circular scales, the inner graduated in centimeters to 99 centimeters, and the outer graduated in half-inch intervals to 39 inches. The dial is about 1⅜ inches in diameter and is similar in appearance to a small watch. The instrument has a swivel handle. Below the dial a housing contains the very small diameter smooth-rimmed measuring wheel. This wheel is connected by gears to the pointer so that correct linear distances will be indicated on the graduated scales when the wheel is revolved over a surface. The swivel handle is attached at an angle of about 15° so that the wheel will always be revolved in the same direction and cause the pointer to travel in a clockwise direction.

The map measure has several advantages over the more common opisometer. Its measuring wheel is only ¼ inch in diameter so that very irregular lines may be easily followed; it has a very free movement, so that it never slips; its movement is endless, so there is no risk of its striking a stop suddenly; and it contains a scale.

Distances on maps or sheets may be measured with the map measure as with the older type of opisometer except that the centimeters or inches measured on the paper may be read directly from the graduated scale and converted into statute or nautical miles by the use of a factor. If the scale has been calibrated correctly—and this should be verified before use—the registered distance in centimeters may be converted for various scales by multiplying by the factors in table 11.

TABLE 11. *Map measure conversion table*

[Multiply distances on map in centimeters by the factors for various scales to obtain statute or nautical miles.]

| Scale of survey | Statute miles | Nautical miles | Scale of survey | Statute miles | Nautical miles |
|---|---|---|---|---|---|
| 1:5,000 | 0.03108 | 0.02698 | 1:60,000 | 0.37290 | 0.32380 |
| 1:10,000 | .06215 | .05397 | 1:80,000 | .49720 | .43173 |
| 1:20,000 | .12430 | .10793 | 1:100,000 | .62150 | .53966 |
| 1:40,000 | .24860 | .21587 | 1:120,000 | .74580 | .64760 |

## *4834. Lettering Sets*

Two types of mechanical lettering sets, manufactured under the trade names of *Wrico* and *Leroy*, are furnished to hydrographic parties. Each type has its particular advantages.

With the Wrico set, letters and numerals, both vertical and slanting, are drawn with a special pen through perforations in celluloid templates. A separate template is furnished for each style and size of lettering. Some letters can be drawn from a single setting of a template, but others require two settings for completion. A spacing device on one end of the template assures the correct placement of the individual strokes of a letter as well as the correct spacing between letters. The pen has a stylus point with ink reservoir, and is provided with a plunger to unclog the point. While the pen is in use the plunger is raised free of the orifice. Various-sized pens are furnished for letters of different thickness.

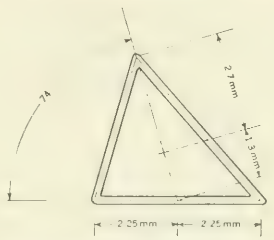


FIGURE 96.—Triangulation station symbol for Leroy template.

The Leroy set consists of templates with deeply grooved letters and numerals, and a special adjustable three-legged scriber. One leg of the scriber follows the grooved letters, a second leg follows a horizontal groove on the template, thus keeping the lettering alined, and the third leg supports a stylus, with which the letters are drawn, and a plunger. As with the Wrico set, pens of various sizes are furnished. A pencil point attachment is also furnished for the scribing arm.

Special symbols may be cut in both types of templates. For example, to adapt the Wrico template for inking triangulation station symbols, a simple equilateral triangle is cut in it; in the Leroy template the guiding triangle is cut through the first lamination but in the shape illustrated in figure 96. A buoy symbol can be made in a similar manner.

After use the pen and its reservoir should be thoroughly cleaned so that ink will not harden in the fine orifice. Cleaning fluids are manufactured for both types of pens. Alcohol may be used to advantage before the ink has begun to harden but it is not effective in dissolving hardened ink.

Lettering sets are furnished to survey parties with templates and pens suitable for use on hydrographic sheets (see **7231**). The Leroy set has the advantage of permitting the draftsman to see the letters better while they are being drawn. Also, a graduated scale on the lower edge of this set facilitates the centering of titles. Faster progress, however, is possible with the Wrico set after the draftsman has developed facility in its use.

### *4835. Paperweights*

Iron paperweights covered with thin leather are obtainable in 1- and 2-pound sizes by requisition on Form 11*a*. After considerable use the leather becomes worn, exposing the metal which will leave marks on the paper on which it is placed. Weights in this condition must not be used on smooth sheets until they have been re-covered. Light weight canvas is a convenient material for this purpose.

An excellent weight may be made by nearly filling a pliable leather or heavy chamois bag with lead shot. The bag should contain about 3 pounds of shot and be securely sewed on all sides. A weight of this type stays in place better than an iron weight and is especially serviceable when the survey vessel is rolling.

## 484. PENS

Pen points used in drafting and lettering and drawing inks are discussed briefly in **725** and **726**.

### *4841. Drop Bow Pen*

The drop bow pen is the most convenient instrument for drawing small circles in ink. It consists of a ruling pen which pivots around a pointed center rod. It may be adjusted by thumbscrew for circles of various diameters. The width of the ink line may also be varied.

On survey sheets, station symbols and all other circles of small diameter are inked with this pen.

### *4842. Ruling Pens*

Ruling pens are used for inking straight lines of even thickness. Those furnished to hydrographic parties are of good quality carbon or stainless steel, usually 6 inches in length with solid blades, one of which springs away from the other when not held closed by a thumbscrew. Pens with such blades have been found to hold their setting better than those with one blade hinged. Adjustment for any desired thickness of line is made by the thumbscrew. It is important that ruling pens be thoroughly cleaned after use.

### *4843. To Sharpen a Ruling Pen*

A ruling pen that has become dull may be sharpened on a fine oilstone if extreme care is used. To restore the nibs to their original parabolic shape, the blades should be brought into light contact, the pen held in a vertical plane and whetted with a back-and-forth motion through an angle of about 120°. To sharpen the pen, the outside surface of each nib is held nearly flat on the surface of the oilstone and whetted with a rotary motion to conform to the shape of the nib, care being taken not to alter the parabolic shape of the ends. The edges should not be too sharp or they will cut the paper.

The bur should be removed from the inside of the blades by using a piece of leather or emery paper.

A method of sharpening ruling pens which requires less skill utilizes emery paper as the abrasive. Emery paper of fine grit such as Norton's 4W4 polishing paper 2/0, or a fine grade of crocus paper, is placed on a base of sponge rubber or a towel folded several times. The ends are shaped on the emery surface as described in the preceding paragraph. The nibs are then opened and the back of each one in turn is placed at an acute angle in full contact with the surface of the emery paper (fig. 97). The pen is repeatedly drawn over the surface of the emery paper, always in a direction toward the handle of the pen, with sufficient downward pressure so that the paper will be depressed into a channel, fitting the contour of the nibs. The pen should be held firmly and prevented from turning, so that the edges of the nibs are in equal contact with the paper. After the desired sharpness has been obtained the inside surface of the nibs should be ground lightly with the emery paper to remove any burs that may have been formed. This method is of particular value in maintaining ruling pens in good condition.

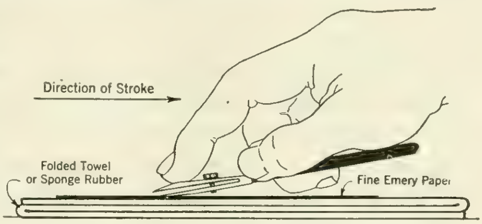

FIGURE 97.—Method of sharpening a ruling pen.

### 485. OTHER DRAFTING INSTRUMENTS

Other drafting instruments, which are not always required but which are peculiarly useful under special circumstances, are described under this heading.

#### *4851. Drafting Machine*

The universal drafting machine combines the functions of a parallel ruler, simple protractor, and scale. It is constructed so that a protractor head may be moved over the surface of a drafting table without change in orientation by means of a parallel-motion linkage consisting of two sets of double bars. The type in which the linkage is provided by two steel bands working against one another is superior to that with pin-joint linkage, because there is less lost motion. The protractor head is a complete circle, graduated in degrees, to which a straightedge is attached which may be clamped at any desired angle. Two straightedges at right angles to each other may be attached to the head.

Any drafting operation requiring straight parallel lines and not too precise an accuracy may be performed advantageously with the universal drafting machine. Bearings, a ship's dead reckoning, or the dead reckoning of a sounding line may be conveniently plotted with it, as well as any navigation line of position. The protractor will retain its orientation accurately enough for such use. Changes in course and direction may be plotted by changing the setting of the straightedge on the graduated circle. In the case of an astronomic line of position one straightedge may be set on the azimuth of the celestial body and the line of position plotted along the other straightedge, at right angles, after it has been transferred along the course to any desired position. The instrument is particularly useful in hydrographic surveying for plotting the bearings and the dead reckoning in connection with R.A.R. control.

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### *4852. Erasing Machine*

An electric erasing machine is of particular value in making small erasures on hydrographic sheets, especially where it is necessary to remove inked detail from small confined areas, since a single sounding or number may be erased without disturbing adjacent detail. It may also be used, if necessary, to remove extensive inking from sheets.

Erasing machines are manufactured by a number of commercial firms and vary in type from an elaborate assembly of electric motor and stand with foot rheostat speed control and flexible cable to which the eraser is attached, to a small inexpensive electric motor with a screw chuck attached directly to one end of the shaft to hold the eraser. The small-type erasing machine is held in the hand and is provided with a starting switch on the motor. The machines are made for 110- and 220-volt a–c or d–c current. Erasers are made in several different grades: a soft pliable grade for erasures of pencil lines and for use on tracing paper, a medium soft grade for pencil or light ink lines on thin drawing paper, and a hard abrasive grade for heavy ink lines on heavy paper.

The effectiveness of an erasing machine is proportional to the speed of rotation of the eraser and does not depend so much on the pressure applied to the paper. Precaution is necessary to avoid wearing a hole through the paper. The correct technique is to move the end of the rotating eraser lightly back and forth or around the surface to be erased. The abrasive eraser should be used with extreme caution and only as a last resort after a softer grade has failed to remove the ink.

### *4853. Pantograph*

A pantograph is an instrument designed to reduce or enlarge maps or drawings to any desired scale. Its construction is based on the principle of similar parallelograms, the essential condition of its design being that three points, one a fixed pivot and the other two movable tracing points, must be in perfect alinement, and each point must be on one of three different sides (or sides produced) of a jointed parallelogram. The ratio of the reduction or enlargement from the original is then equal to the ratio of the distances of the movable points from the fixed pivot.

Pantographs vary from an expensive suspended precision type of all-metal construction to an inexpensive instrument of four wooden bars fitted with metal joints. Its principal use in the Coast and Geodetic Survey is in the reduction of topographic and hydrographic surveys. The instruments used in the Washington Office are of the precision type with three of the four metal bars graduated. Different scale settings are made by moving the graduated cross bar identical amounts on its supporting arms with a corresponding movement of the tracing point support on that bar.

To make reductions, the original is traced with the point farther from the pivot, the nearer point following its movement to draw a reduced replica of the original. For use in chart construction the reductions made in the Washington Office are carbon impressions on transparent paper. A carbon paper is placed, carbon side up, beneath the transparent paper and as the metal point on the cross bar moves, the reduced detail is impressed on the underside of the transparent paper. The detail is then

transferred to the map or chart by fitting the impression in place and burnishing the detail.

The setting for a pantograph to be used in making a reduction may be found from the formula,

$$S=\frac{b\times f}{a}$$

in which $S$ is the setting for the three graduated arms, $a$ is the distance, measured with any convenient scale, between any two points on the original to be reduced, $b$ is the distance between the same two points at the required reduction, measured with the same scale, and $f$ is the factor of the pantograph, which is 960 for most of those used by the Coast and Geodetic Survey. The use of the pantograph for reduction is limited to a ratio of about 1 to 20, or a setting on the arms of 48.0. For smaller ratios two reductions are required, in which case the first should be made at a ratio of about 1 to 4 and the second at a ratio chosen so that the product of the two ratios will be equal to the total reduction desired.

### *4854. Projector*

A projector is an instrument by means of which the image of one survey may be projected through a lens onto another survey sheet at a different scale. Projectors vary from simple assemblies to elaborate commercially manufactured instruments. They are not generally used on board survey ships because the limited vertical space is not sufficient and the projectors in common use require a firm foundation. They are especially valuable in the Washington Office and in field plotting offices.

The simplest projector is one in which the detail on a transparent sheet is projected vertically downward through a bellows-and-lens assembly at varying scales.

The projector in general use in the Coast and Geodetic Survey is designed so that detail may be transferred, by means of a reflected image, from opaque as well as transparent sheets. It consists of a stationary lower horizontal table and a movable upper assembly containing a vertical table, the bellows and lens, the lights, and a front-surface mirror inclined at an angle of 45° to both tables. The lens and bellows are mounted under the light-tight box directly below the mirror so that the projected image will appear approximately in the center of the lower table. The vertical distance between the lower table and the upper assembly, and the distance between the lens and the mirror, may be varied by suitable attachments. The arrangement of the lens and the mirror with respect to the two tables results in the projection of a direct image of the subject onto the lower table, thus permitting the ready transfer of the detail.

In use, the sheet containing the detail to be transferred is attached to the upper table, and the sheet to which it is to be transferred is placed on the lower table. The lower sheet is oriented to fit the upper sheet and the reflected image of the upper sheet is brought to the scale of the lower one by means of a vertical movement of the upper assembly and a separate vertical movement of the lens with reference to the mirror. The correct setting is determined visually. When the projected detail is in scale agreement with the lower sheet and the projected image is in sharp and clear focus a perfect setting has been attained.

A projector should be tested occasionally to make certain that the plane of the upper table is accurately projected to the plane of the lower table. This is done by placing a square grid on the upper table and projecting it to an identical square grid on the lower table at a ratio of 1 to 1. If the projected image coincides on all sides, the projector is in adjustment. If perfect coincidence is not obtained, the upper table or mirror should be adjusted by means of the attachments provided for that purpose.

## 486. Requisitions for Drafting Materials

Drafting materials needed by hydrographic parties and field plotting offices are furnished from the Washington Office. Requisition should be made on Form 11*a* for items listed on Form 11, Catalog of Forms and Stationery, and by ordinary letter for other items. When requisition is by letter, it must contain no other subject matter. The type and size, as well as the quantity, of the items desired must be clearly indicated.

The following items should be requisitioned on Form 11*a*:

- Drawing paper, boat sheet, buff (specify width)
- Erasers
- Ink, drawing
- Paperweights
- Pen points
- Pencils, drawing
- Pencil pointers, emery
- Penholders
- Protractors, paper
- Shields, erasing
- Thumbtacks
- Tracing cloth
- Tracing paper

The following items should be requisitioned by letter:

- Aluminum plates, grained or painted
- Celluloid protractors, circular
- Celluloid protractors, semicircular
- Celluloid sheets
- Drawing paper, aluminum-mounted
- Drawing paper, smooth sheet, white (specify kind and width)
- French curves
- Ink, celluloid
- Pen points, special
- Rubber cement, nonvulcanizing
- Scotch tape (cellulose or masking)
- Tracing paper or cloth, special grades
- Triangles, celluloid

# CHAPTER 5. ECHO SOUNDING

## 51. GENERAL STATEMENT

### 511. PRINCIPLES OF ECHO SOUNDING

Echo sounding is a method of measuring the depth of water by determining the time required for sound waves to travel, at a known velocity, from a point near the surface of the water to the bottom and return. Everyone is familiar with echoes in air and realizes that they are caused by reflections of sound from some distant object back to the listener. If the time is measured between the production of a sound and the reception of its echo, the distance to the reflecting surface may be determined by multiplying one-half the time interval by the velocity of sound in air. Since the time interval is a measure of the entire journey, only half the interval is used to find the distance to the reflecting object.

The same principles are applied in measuring water depths by echo sounding. A sound is produced in the water near the surface; it travels to the bottom, from which it is reflected back to the surface as an echo. Echo-sounding equipment is designed to produce the sound, receive and amplify the echo, measure the intervening time interval, and convert this interval automatically into units of depth measurement, such as feet, fathoms, or meters.

It is common knowledge that echoes in air can be heard only in certain localities, and can be heard better under certain favorable conditions. This is because a surface, well shaped to reflect the sound, is required at not too great a distance and conditions must be favorable for transmission of the sound, so that it will not be attenuated to such a degree that it cannot be heard. It is fortunate for echo sounding that echoes are much less difficult to obtain from the ocean bottom than they are from objects in air. There are several reasons for this: first, there is always a reflecting surface, the sea bottom, that generally acts as a good reflector of sound; second, sound in water is not subject to as much absorption or to such large variations of attenuation as sound in air and, because of less absorption, sound in water will travel many times as far with reference to the point of origin as sound of the same initial intensity will in air; and last, water possesses characteristics favorable to echo sounding, such as a reasonably constant velocity of sound.

Continuing the comparison of echo soundings with the more familiar case of echoes in air, it is well known that an echo follows immediately after the original sound if the reflecting surface is near, and in order for the echo to be heard, the original sound must be of very short duration. In the case of echo sounding this condition is aggravated, for sound in water travels more than four times as fast as it does in air. Because of this higher velocity the sound signals used for echo sounding in shoal water must be of extremely short duration.

Sound is a disturbance that is propagated through an elastic medium by means of the condensation and rarefaction of the medium, the velocity of propagation depending on certain physical characteristics of the medium. Sounds in water are produced with approximately the same ease and by the same methods as sounds in air are produced. Most modern echo-sounding instruments generate sound in the water by means of a

vibrating surface in contact with the water. This is commonly known as an oscillator, or transmitting unit. The surface, or diaphragm, may be made to vibrate by either electric or mechanical means. The alternate condensation and rarefaction of the water produced by the vibrating surface are transmitted to the adjacent layers of water, and the sound wave travels away from its source at a velocity of approximately 4,900 feet per second. The transmitting unit has an effect in water similar to that of a radio loudspeaker in air.

Echo-sounding instruments employ a receiving device, whose function is similar to that of a telephone transmitter, to detect the echo. This device is referred to as the receiving unit, or sometimes a hydrophone. The receiving unit is immersed in the water in a favorable position to receive the echo, and it converts the sound energy into electric energy. As this electric energy is very small it must be amplified by means of a vacuum-tube amplifier.

The accuracy of echo soundings is directly dependent on a knowledge of the velocity of sound and on the precision with which the travel time of the sound can be measured. Numerous devices of varying precision are utilized to measure the travel time. They constitute timing parts that operate in conjunction with the registering device of the instrument.

Although echo soundings are primarily measurements of the time required for the sound to travel from the surface of the water to the bottom and return, the time units must be converted into depth units to be of practical use. That part of the echo-sounding equipment that measures the time interval in terms of depth is known as the registering device. It may record the echo graphically or indicate it visually. The function of the registering device is to control the timing of the original sound with reference to a depth scale and to register the receipt of the echo on the same scale, the depth indicated corresponding to the elapsed time.

All types of echo-sounding equipment contain parts, in one form or another, which perform these separate functions, all arranged to operate collectively. To illustrate the relations between the various parts and the contribution of each to the whole operation, a complete sounding cycle is described. A timing mechanism in the instrument, at a precise instant, actuates the transmitting unit to emit a sound of short duration in the water. This instant is usually near the zero of the depth scale. The sound travels downward, is reflected from the ocean bottom, and returns as an echo to be detected by the receiving unit, or hydrophone. The electric energy generated in the receiving unit by the echo is increased sufficiently by the amplifier to register on the depth scale at a point corresponding to the echo-travel time. This process is continuous, the cycle of transmitted sounds and received echoes being repeated in rapid succession.

The range of water depths that can be measured by echo sounding is practically unlimited. Soundings have been taken in depths from a few inches below a transmitter to the greatest ocean depths (about 6,000 fathoms)—one echo-sounding instrument is usually incapable of this, as instruments that are designed for accurate soundings in shoal water are usually not suitable for soundings in deep water, and vice versa.

The ease and rapidity with which water depths can be measured by echo sounding, for use in navigation or hydrographic surveying, is remarkable as compared with other means; and the results obtained with a properly adjusted instrument, if adequately corrected, are far more accurate than those obtained by the older methods. Echo soundings are not subject to the inherent uncontrollable errors and difficulties associated with the leadline, wire, and other depth-measuring devices. The deepest echo soundings

may be obtained in a few seconds from a vessel proceeding at full speed, in contrast to an hour or more that may be required to obtain a wire sounding of similar depth from a ship stopped in the water. Echo soundings can be obtained so frequently in shoal water, many hundreds per minute with some instruments, that a nearly continuous profile of the bottom can be made while the vessel is moving through the water at normal speed.

Echo-sounding equipment may be employed on vessels ranging in size from a small rowboat to the largest ocean-going ship. The equipment is generally permanently installed on a vessel, and considered part of the navigation or survey equipment; however, portable instruments are sometimes used that can be temporarily installed and removed as desired. This latter type of instrument is particularly adapted for use on small vessels and launches.

In this chapter are included detailed descriptions of specific types of echo-sounding equipment and their operation, general limitations, classifications, and functions of parts, with particular emphasis on those types used in hydrographic surveying by the Coast and Geodetic Survey.

## 512. History of Echo Sounding

The principles of echo sounding were formulated well over a hundred years ago and attempts were made shortly thereafter to reduce those ideas to practical application. But only in recent years has echo sounding been developed to a stage of practical usefulness.

History discloses numerous observers who noted the fact that sounds could be heard under water, but apparently no one suggested that such sounds might be used for the measurement of distance and depth until 1807, when a French physicist, Dominique François Jean Arago, made the specific proposal that water depths might be measured by utilizing the propagation of sound. Unfortunately, Arago's ideas remained little more than a proposal. In the following years several unsuccessful attempts were made to measure depths by sound, but these failed because of lack of proper equipment and the meager knowledge of acoustics that existed at that time. Among the early experimenters in underwater sound were Colladon and Sturm who in 1827 devised a means of measuring horizontal distances and made a fairly good determination of the velocity of sound in Lake Geneva. In 1837 Charles Bonnycastle made unsuccessful attempts to hear echoes in water and in 1854 the great American navigator and scientist, Matthew F. Maury, attempted to obtain echo soundings, by discharging gunpowder under water, also without success. Had he listened under the water for the echo his experiments might have proved successful.

It was more than one hundred years after Arago's proposals that the first actual means for obtaining echo soundings was devised. One of the earliest patents based on echo-sounding principles was issued to A. F. Eells of the United States in 1907. It is not known whether Eells' equipment was successful, but his conception of echo-sounding principles was far ahead of his day. Dr. Alexander Behm of Germany is given credit by many for the first echo soundings. His early experiments consisted in firing cartridges in the water and recording the echoes photographically. Much of Behm's success and that of later experimenters can be attributed to the gradual accumulation of knowledge in the field of acoustics and related sciences since the time of Arago.

The sinking of the *Titanic* in April 1912, by a collision with an iceberg, motivated Behm and others to devise methods of preventing similar disasters. Attempts to receive echoes from the submerged portions of icebergs led to the development of

equipment whose greatest ultimate usefulness was not that originally intended, but in obtaining echoes from the ocean bottom. Professor R. A. Fessenden of the United States was also stimulated by the *Titanic* disaster to experiment with echoes in water, one of the principal results of which was the development of a powerful oscillator which could produce sounds of great intensity in water. He also developed an instrument to convert sound travel time to distance. Unfortunately this instrument was never perfected to the full stage of usefulness. A few years later Langevin and Chilowski, of France, succeeded in developing supersonic-sounding apparatus beyond the experimental stage. This was significant because most modern echo-sounding instruments utilize sounds of supersonic or near supersonic frequencies.

World War I was responsible for advanced knowledge of and developments in subaqueous acoustics. Large groups of eminent scientists applied their talents to the development of submarine-detecting and signaling devices, and numerous other underwater sound aids to navigation. During the years immediately after World War I there was increased activity in the development and use of echo-sounding equipment, the major developments being made by commercial companies and the governments of the United States, England, France, and Germany.

Between the years 1918 and 1925 many important experiments led eventually to the practical application of echo sounding for use in navigation and surveying. During this period sounding apparatus was being rapidly developed and a knowledge of the extent of the usefulness of echo soundings was being acquired as well. Among the many important developments and experiments of a practical nature during this period, the following are selected as being representative and especially notable, although others may be considered of equal importance:

(1) The application of submarine-listening microphones to echo sounding by the United States Navy in 1918.

(2) In 1919 the French Hydrographic Department obtained echo soundings to a depth of 60 meters in the Casquets Deep from a ship underway at 10 knots.

(3) In 1919 soundings in depths of 4,000 meters were obtained in the Bay of Biscay from the cable ship *Charente*.

(4) The first line of supersonic soundings was run in 1920 by the Centre d'Etudes de Toulon.

(5) In 1922 the French Hydrographic Department, using a Marti sonic apparatus, ran a line of sonic soundings to explore the depths between Marseilles and Philippeville, preparatory to laying a cable between these points. This is claimed to be the first practical application of echo sounding.

(6) In 1922 a profile of soundings between Gibraltar and Port Said was obtained from the U. S. S. *Stewart*, using the Hayes Sonic Depth Finder developed at the Annapolis Engineering Experiment Station of the United States Navy.

(7) In 1923 an important contribution to echo sounding was made by Dr. Herbert Grove Dorsey of the United States, who devised a visual-indicating device for measuring extremely short time intervals, by which shoal and deep depths could be automatically registered. This method of registration is embodied in many of the echo-sounding instruments in use today.

The period since 1925 has been significant for the refinement of apparatus and further development of the theory of acoustics. The application of echo sounding has been extended to a range from very shoal to very great depths. The accuracy and reliability of echo soundings have been increased by instrumental refinements and a more extensive knowledge of the effective velocity of sound in water. The use of thermionic tubes in echo-sounding circuits has made many of the refinements possible.

Sonic frequencies were used almost exclusively in the early stages of development of echo sounding by all except the French. Sonic sound-producing devices, such as hammer strikers, explosions, and electromagnetic oscillators, have been employed.

But in recent years supersonic frequencies have been increasingly employed in echo-sounding equipment, both for navigation and surveying purposes. This has been made possible by the theoretical study and practical application of magnetostriction and piezoelectric phenomena.

Important advances have been made in graphic recording, in early use in Europe, as a method of registering echo soundings. This method of registering soundings has only recently been adopted for extensive use in the United States.

Besides its value in hydrographic surveying and navigation, echo sounding has been used for such varied purposes as the measurement of tides at sea, the measurement of silt deposits on the sea bottom, and the collection of valuable data for geologic and erosion studies.

## 513. History of Echo Sounding in the Coast and Geodetic Survey

### *5131. Sonic Depth Finder*

The first echo-sounding instrument used by the Coast and Geodetic Survey was installed on the ship *Guide* in 1923 and was first used to take deep oceanic soundings during a voyage from Norfolk, Virginia, to San Diego, California. This apparatus was known as the Sonic Depth Finder, developed by Dr. Hayes of the United States Navy. The following year a similar instrument was installed on the ship *Pioneer*. In operation, the Sonic Depth Finder transmitted a sound in the water at the precise instant the echo from a previously transmitted signal was heard. The operator used a set of headphones, through which he could hear the transmitted signal through one ear and the echo through the other. By a variable-speed mechanism the operator could vary the interval between transmitted sound signals, until the transmitted sound and an echo were heard simultaneously. The position of the dial on the variable-control mechanism served to indicate the depth. Although the Sonic Depth Finder was far superior to earlier sounding instruments it had numerous shortcomings as a hydrographic survey instrument. Among these may be mentioned the inaccuracy of soundings obtained in depths of less than a hundred fathoms even when a special shoal-water device was used; the likelihood of inherent erroneous soundings due to the principles of the instrument; and the personal error, because the accuracy of depth measurements depended on the skill of the operator.

### *5132. 312 Fathometer*

In 1925 the first Fathometer (pronounced Făth′ ŏ-mē′ tĕr), a commercial instrument designed and built by the Submarine Signal Company, was installed on the ship *Lydonia*. This instrument, known as the 312 Fathometer, was later installed on all the ships of the Coast and Geodetic Survey and entirely replaced the Sonic Depth Finder. Most of the objectionable features of the Sonic Depth Finder were eliminated from the 312 Fathometer; comparatively shoal soundings could be obtained, the soundings could be read visually from a depth scale, little experience was needed to operate the instrument, and all soundings could be taken from the vessel while underway. Deep-water soundings were obtained on the 312 Fathometer by noting the position on a circular depth scale of a continuously rotating white light, at the time the arrival of the echo was heard in the operator's headphone. This method was known as the white-light method but was later replaced by a red-light method similar to that used to obtain soundings in shoal to moderate depths. The red-light method utilizes a

465382—44——30

rotating neon tube which flashes adjacent to the depth scale at the instant of arrival of the echo, thus acting as an index to indicate the depth. The 312 Fathometer is still used on some ships of the Coast and Geodetic Survey. (See **521**.)

### *5133. 412 Fathometer*

A 412 Fathometer, a striker type of instrument, was installed on the motor vessel *Natoma* in 1928, and subsequently other models, similar in principle to the 412, were installed on several ships. Finally all the striker types of Fathometers were discarded because they did not give results sufficiently reliable and accurate for survey purposes. (See **5161D**.)

### *5134. Dorsey Fathometer No. 1*

Echo sounding proved to be a much more accurate, faster, and easier method of hydrographic surveying than any method previously used. However, most of the instruments available in the United States prior to 1935 were designed for use on commercial vessels and, while sufficiently accurate for navigation, they did not fully meet the requirements of the hydrographer.

A precision instrument was needed with which soundings between a few feet and 20 fathoms could be obtained with far greater accuracy than with any existing instrument. The design of such an instrument was started in 1933 in the Washington laboratory of the Coast and Geodetic Survey. This first instrument of its kind was installed on the *Lydonia* in 1934. It was named later the Dorsey Fathometer No. 1, a detailed description of which is given in **524**. The Dorsey Fathometer No. 1 was so successful that similar instruments were installed in subsequent years on all ships of the Coast and Geodetic Survey operating on the East and Gulf Coasts. Although designed primarily for use in depths of 20 fathoms or less, soundings have been obtained in 150 fathoms, although 40 fathoms is usually the maximum depth in which it is used. The Dorsey Fathometer No. 1 uses a frequency of sound very close to supersonic; this was the first attempt by the Coast and Geodetic Survey to use the higher-frequency sound waves in echo sounding.

### *5135. Dorsey Fathometer No. 2*

In 1937 the Dorsey Fathometer No. 2 was designed to supplement the Dorsey Fathometer No. 1. It incorporated many of the performance and accuracy features of the No. 1 model but, whereas the latter was designed especially for use in depths less than 20 fathoms, the No. 2 model was designed for depths greater than 20 fathoms. The first two instruments of this type were installed on the *Oceanographer* and the *Hydrographer*. (See **525**.)

### *5136. Dorsey Fathometer No. 3*

Performance of these two models of Dorsey Fathometers proved so satisfactory that their features were combined into a single instrument, known as the Dorsey Fathometer No. 3, for use in all depths. The first of these instruments was constructed in the laboratory of the Coast and Geodetic Survey and was installed on the motor vessel *Westdahl* in 1938. This first instrument gave satisfactory results and Fathometers of this type were later installed on most of the ships of the Coast and Geodetic Survey, and were still in use in 1941. (See **526**.)

### *5137. Other Instruments*

In 1939 a Hughes Veslekari deep-water graphic-recording instrument (**527**), of British manufacture, was installed on the ship *Oceanographer* and a year later a similar instrument was added to the sounding equipment of the ship *Explorer*. Also, in 1939 performance tests were made on a Hughes portable graphic-recording instrument *MS* 12 *D* (**528**). The value of such an instrument for use in hydrographic surveys made from launches and small boats was at once apparent. Specifications were prepared for a portable graphic-recording instrument particularly adapted to meet the requirements of the Coast and Geodetic Survey. The 808 Fathometer (**523**), built by the Submarine Signal Company, resulted from these specifications and was first put into service in 1940. In actual field use during that year this instrument gave excellent results although minor faults were disclosed which were subsequently corrected during the winter 1940–41. Although primarily intended for use on launches as a semiportable instrument, a few permanent installations have been made on larger vessels.

## 514. GENERAL LIMITATIONS OF ECHO SOUNDING

Certain general limitations are encountered in echo sounding that tend to limit the useful range of the instruments and influence the accuracy of the results. These limitations may be divided into two broad classes; those due to the properties of the medium through which the sound passes, and those embodied in the echo-sounding equipment.

The transmission of the acoustic waves used in echo sounding is dependent on certain properties of the medium, or on the result of certain external influences on this medium, and on the reflecting surface. For echo soundings the medium is the water through which the sound passes and the reflecting surface is the sea bottom. Ideally, for echo sounding, they should possess the following characteristics: constant physical characteristics throughout the entire depth of water, resulting in a constant velocity from surface to bottom; zero attenuation of sound; and 100 percent reflection from a bottom parallel to the water's surface. In practice these ideal conditions never exist; nevertheless echo sounding under the existing conditions gives results satisfactory for most purposes. Some of the conditions that influence echo sounding are (1) salinity of the water, (2) temperature of the water, (3) type of bottom, (4) aeration, (5) absorption, and (6) turbulence. Some of these factors are interrelated.

Many of the factors that limit the use and accuracy of echo-sounding instruments are inherent and basic and therefore can be controlled only to a limited degree. There are others, however, which are controllable to a greater extent and, unquestionably, ways will be found to control them in increasing degree as the science of echo sounding progresses.

### *5141. Absorption*

As the sound passes through the water some of its intensity is lost and hence, under certain conditions, the echo may be so weak that it cannot be detected. Sound, like other forms of energy, suffers a loss in intensity due to friction, which is referred to as the loss due to the viscosity of the medium. This loss of sound energy is by conversion to heat and is sometimes referred to as absorption. Absorption of this nature is important only when high supersonic frequencies are employed, and may be ignored at sonic frequencies.

### *5142. Radiation*

The sound leaving the transmitting unit does not travel in parallel rays, but radiates from the source. In sounding, only that part of the sound which is reflected back from the bottom directly under the vessel is of practical importance and the remainder, which travels in other directions, represents a complete loss of energy. This loss might be utilized to produce a stronger echo if concentrated in a direction normal to the bottom. This divergence of the sound represents one of the largest losses of useful energy—because of the spread, at a greater depth a smaller percentage of the total energy reaches the receiving unit.

### *5143. Aeration*

Sound energy is also lost through aeration, which is the suspension in water of air in the form of bubbles. The movement of a vessel through the water mixes air with the water along the bottom of the vessel, to an extent that it may even completely envelop the bottom. Sound waves are partly reflected, or dispersed, and partly absorbed by aeration; theoretically when the air in the water represents 10 percent by volume of the water, total reflection of sound will take place. In passing through this aerated lamina, sound suffers a loss which in extreme cases is equivalent to complete attenuation of the sound signal. Moreover, the returning echo will be attenuated equally as much as the outgoing sound. During rough weather aeration may be sufficient to preclude the use of echo sounding. The shape and size of the hull and the speed of a vessel influence the extent of aeration, it being more extensive on small and shallow-draft vessels. When a vessel is going astern the propeller will generally draw sufficient air under the hull to prevent the detection of any echoes.

### *5144. Reflections*

Echo sounding depends on receiving the reflection of sound from the sea bottom. Thus, in addition to other types of attenuation echoes are subject to the limiting factors of the configuration and composition of the bottom. The relief and slope of the bottom may be such that the reflected sound is scattered or dispersed so that little or none of the echo signal is received at the vessel. The composition of the bottom is an important factor in the intensity of the echo. Nearly 100 percent of the incident sound waves will be reflected from a flat bottom of homogeneous composition, such as sand, rock, or packed mud, while a prolonged echo of weakened intensity may be expected from a bottom of spongy nature, such as unconsolidated mud or silt deposits, or from a bottom on which there is an abundance of marine growth.

Any discontinuity of the medium between the water surface and the bottom, from which the sound can be reflected, reduces the echo intensity. That energy which is reflected before reaching the bottom as well as that reflected back to the bottom before reaching the surface represents a loss in echo effectiveness. Such factors as changes in water density, turbulence, aeration, and solid matter in suspension in the water may form sufficient discontinuity so that internal reflections take place in the medium. These are generally only minor limitations, but may become important in rivers, and in certain regions where the commingling of waters of different temperatures and densities occurs, and where salt wedges and colloidal suspension exist.

If the path of the transmitted sound is not perpendicular to the bottom, part or all of the echo may be lost, as the sound will strike the bottom at an angle and be reflected away from the vessel. This may occur when heavy seas cause the vessel to pitch or roll

excessively. Attenuation of the echo for this reason is intensified where the transmitted signal is directive, in the form of a narrow beam or cone, as is usual with supersonic-sounding instruments. This limitation is aggravated by the additional fact that, even though the sound may be reflected from the bottom in a normal manner, the echo may not be detected if the receiving unit, which may also be directional, is at an unfavorable angle for its reception at the instant of its arrival.

### *5145. Echoes From Sloping Surfaces*

The depth registered by the echo-sounding instrument is not the true depth under the vessel under all conditions. A hydrographer experienced in echo sounding can frequently recognize these unfavorable conditions and sometimes a proper correction can be applied. In sounding over rugged submarine relief, the sound may be reflected back from a multitude of surfaces and a prolonged echo may be received, no part of which is from the bottom directly under the vessel. The sound from a nondirective transmitter is reflected first from the nearest reflecting object and this part of the echo is likely to be more intense than any subsequent part, and might be interpreted erroneously as the correct depth. Such echoes are known as side echoes or reflections from slopes. Echo-sounding instruments employing directive signals avoid, to some extent, these confusing side reflections, but still are not entirely free from them.

As mentioned in **5144**, certain discontinuities in the physical characteristics of the water or the accumulation of foreign matter in the water, may cause reflections which may be erroneously interpreted as those from the bottom. This is not a common occurrence but reflections have been received from density interfaces and foreign matter such as kelp, which have been difficult to distinguish from echoes from the bottom.

From certain types of bottom, the echo is not a single clear-cut sound, but a series of reflections from various points on the bottom, at varying distances from the vessel. Although one of these numerous reflections may be from vertically below the vessel, the selection of the proper echo may be difficult. A graphic record has the great advantage, in such a case, of making possible a careful and lengthy examination to select what appears to be the correct depth.

Additional discussion of this limitation is included in **563**.

### *5146. Multiple Echoes*

Multiple echoes are those received subsequent to the first echo, and are due to a multiplicity of reflections back and forth between the bottom and surface. These reflections often register on the dial of a visual indicator, or on the fathogram of a graphic recorder, at multiplies of the true depth. Such echoes are sometimes mistaken for the first echo. As many as 12 echoes of the transmitted sound have been observed in extreme cases. This condition can be controlled to some extent by reducing the amplification of the echo until all the echoes disappear except one, the result of a single reflection.

### *5147. Strays*

At times spurious, or false, indications appear on the dial or fathogram of an echo-sounding instrument, which either may be mistaken for the true echo or may be of such a nature as to prevent identification of the true echo. These spurious indications are known as *strays*. They may be caused by the motion of the vessel through the water, by acoustic or electric noises in the ship, or by electric noises in the echo-sounding equip-

ment. During rough weather when the vessel is pitching or rolling violently the number and intensity of strays on the registering device may be sufficient to obscure all soundings. Strays caused by the motion of the vessel usually come in groups, between which it is usually possible to detect a few true soundings. The acoustic noises originating in the ship, which cause strays, generally come from some parts of the machinery, such as the main engines, pumps, clapper valves, or auxiliary equipment, but they may also be caused by chipping or similar work performed on some part of the ship's hull. Electric noises, generated either in the ship or in the echo-sounding equipment, may have such a periodicity of recurrence that they appear as echoes on the registering device. When the echo is weak, as it may be in deep water, strays are more bothersome, since their intensity level is then relatively higher. It is necessary in this case to increase the gain of the amplifier to build up the weak echo, but the spurious noises are thereby also amplified in the same proportion.

### *5148. Velocity of Sound*

The accuracy of echo soundings is directly dependent on an accurate knowledge of the velocity of sound in the water. This velocity is subject to regional, seasonal, and diurnal variations. Echo-sounding instruments are operated for a certain assumed velocity of sound, known as the calibration velocity, and any depth measurement is, therefore, in error by an amount directly proportional to the variation of the actual from the assumed velocity. This variation is a matter of concern in hydrographic surveying. Correction must be made for it, and an unknown or unexpected variation may introduce errors greater than the allowable limits. (See **561**.) Systematic measurements of the physical characteristics of the water are made to determine the exact velocity so that the measured depths may be corrected to be within at least one-half percent of the true depth.

The velocity of sound in sea water, averaged from surface to bottom, in any of the waters of the earth is usually within a range of 4,560 feet (760 fathoms) to 5,100 feet (850 fathoms) per second. In the areas usually surveyed by the Coast and Geodetic Survey the average velocity has been found to be about 4,920 feet (820 fathoms) per second. If an average velocity of 820 fathoms per second is assumed, the maximum error of uncorrected echo soundings in any locality will be 8 percent. Generally the actual velocity does not vary materially from the assumed average and uncorrected echo soundings are, therefore, sufficiently accurate for use in navigation. (See also section **63**.)

## 515. General Classification of Echo-Sounding Instruments

Echo-sounding instruments may be classified in various ways; for example, according to their use, the frequency of the sound utilized (sonic or supersonic), or the type of registering device used. Or, in order to give a more complete description of the type of instrument, combinations of these classifications are employed; for example, a particular instrument may be called a shoal-water, graphic-recording, supersonic, echo-sounding instrument. Classifications as to use may be further subdivided according to the service for which the instrument is intended or the depth range of the instrument.

Except for some specialized uses, most echo-sounding instruments are intended for use in either navigation or hydrographic surveying. This does not necessarily mean that an instrument designed for one purpose cannot be used for two or more purposes.

But instruments for use in navigation are constructed with a view to getting soundings rapidly, with a fair degree of accuracy, and with a minimum of adjustment and maintenance; and they must be simple in construction, which prohibits the refinements necessary in a survey instrument.

### *5151. Depth Range Classification*

As to depth, echo-sounding instruments may be broadly classified as shoal, moderately deep, and deep-water instruments. The depths are those in which the instrument was designed to sound most efficiently. For purposes of classification, shoal depths may be considered to be those from 0 to 20 fathoms, moderate depths those from 20 to 100 fathoms, and deep water all depths of more than 100 fathoms. Some instruments of special design may be equally effective throughout the entire depth range and therefore cannot be conveniently classified in this manner.

The echo-sounding instruments used by the Coast and Geodetic Survey may be classified as to depth range as follows: for shoal water—Dorsey Fathometer No. 1; for shoal and moderately deep water—808 Fathometer, Simplex-Bludworth Fathometer, and the Hughes *MS* 12*D;* and for moderately deep and deep water—312 Fathometer, Veslekari Graphic Recorder, and Dorsey Fathometer No. 2. The Dorsey Fathometer No. 3 may be considered as included in all these classifications, since it embodies the features of both the Dorsey Fathometer No. 1 and No. 2 as well as the 312 Fathometer.

### *5152. Frequency Classification*

When echo-sounding equipment is classified according to the frequency of the transmitted sound, it is said to be either sonic or supersonic. Devices that utilize acoustic waves of a frequency that are audible to the human ear are generally classified as sonic instruments; and those that utilize frequencies above auditory perception are called supersonic, or ultrasonic, instruments. There is a close relation between the classification of echo-sounding instruments by depth and by frequency. This is because each range of frequencies has distinct advantages for use in a certain depth range.

#### A. SONIC FREQUENCIES

Echo-sounding instruments used in navigation, especially in the United States, employ sonic frequencies to a large extent. These frequencies can be generated in the water at a high-energy level with relatively simple and inexpensive equipment. Because of the low absorption at sonic frequency, their high penetrating power also makes them useful for deep soundings. Sound-producing and receiving units can be made to convert energy very efficiently at sonic frequencies, which adds to the total efficiency of the system.

Sonic frequencies have, on the other hand, certain restrictive limitations. These frequencies cannot be used to measure extremely shoal depths with a high degree of accuracy, because the period of these frequencies approaches the time interval to be measured. Most of the energy of water and ship noises is in the sonic-frequency range and, therefore, sonic soundings are more susceptible to interference by strays. Because of their long wave lengths these low frequencies cannot be directed, or *beamed*, to an advantageous degree, without using transmitting and receiving units of a prohibitive size.

Directivity is desirable because it adds to the discrimination against spurious noises, in addition to concentrating the sound energy in the desired direction. Sonic frequencies do not permit as minutely detailed a representation of the bottom as might be desired in some cases. This is especially true where the bottom irregularities are small compared to the wave length of the sound employed.

#### B. SUPERSONIC FREQUENCIES

Supersonic frequencies overcome, to a large extent, most of the disadvantages of sonic frequencies and still possess many of their advantages. The advantages of supersonic frequencies are:

(1) High directivity with small transmitting and receiving units.

(2) Concentration of sound energy, because of directivity, in the desired direction, i. e., normal to the bottom.

(3) Discrimination against spurious noises by reason of directivity and because of the generally lower frequency of the ship and water noises.

(4) Measurement of shoal depths because a shorter signal can be made.

(5) Detailed profile of irregular bottom due to the short wave lengths.

(6) Reduction of side echoes because of the narrow beam of sound.

Supersonic frequencies are used in both navigation and survey echo-sounding instruments, and are employed in all depths from the shoalest to the deepest. Greater attenuation of sound occurs at these higher frequencies and the sound waves are more likely to be reflected within the medium. While these are hindering limitations they are serious only in extreme cases.

Only one type of echo-sounding instrument used by the Coast and Geodetic Survey employs sonic frequencies exclusively; this is the 312 Fathometer. Those which are classified as supersonic instruments are the Dorsey Fathometer No. 1, the 808 Fathometer, the Simplex-Bludworth Fathometer, the Veslekari, and the Hughes *MS* 12 *D*. The Dorsey Fathometer Nos. 2 and 3 are combined sonic and supersonic sounding instruments.

### *5153. Registering Device Classification*

A common method of classifying echo-sounding equipment is by reference to the method of depth registration. There are two broad classifications; the visual and the graphic-recording types. This classification is irrespective of the kind of acoustic signals employed or whether the instrument is intended for navigation or surveying. On a visual indicator the depth can be read quickly and accurately but it must be observed constantly if a profile is desired. It is of most value when only an occasional sounding is desired. The visual indicator types used by the Coast and Geodetic Survey, because of their design, do not register silt deposits less than 2 fathoms thick. The principal advantage of the graphic-recording type is that it makes a permanent record of a profile of the bottom, whose details may be examined at leisure at any later date. Unusual characteristics of the bottom, such as silt layers and the underlying substrata, are often registered by a graphic-recording instrument. All these features are of special value to the hydrographer.

Instruments used by the Coast and Geodetic Survey classified as visual types are the Dorsey Fathometer Nos. 1, 2, and 3, and the 312 Fathometer. Those classified as graphic recording are the 808 Fathometer, the Simplex-Bludworth Fathometer, the Veslekari, and the Hughes *MS* 12 *D*.

## 516. Description and Function of Parts

Every echo-sounding instrument is composed of three principal parts, which perform individual functions, the combination of which results in a depth measurement. The three parts are: the acoustic transmitting unit or sound producing part, and the source of energy to operate this unit; the acoustic receiving unit and the echo amplifier; and the registering device, including a motor whose speed is controlled, an index and depth scale, and the necessary keying circuits. Under the following headings are given descriptions and functions of each of the principal parts, and a brief summary of the different kinds of equipment used to perform these functions.

### *5161. Acoustic Transmitting Units*

The function of the transmitting unit is to generate acoustic waves in the water with sufficient intensity and duration so that an echo can be received from the bottom, of sufficient strength to be amplified to register the depth. Acoustic waves are ordinarily generated in the water by the motion, or vibration, of a surface or diaphragm, which alternately condenses and rarefies the water next to it, thereby starting a train of acoustic waves that is propagated away at the velocity of sound. The transmitting unit may have its emitting surface in direct contact with the sea water or the entire unit may be enclosed in a water-filled tank, the acoustic waves passing through the ship's plates. The transmitting unit is frequently housed in an internal water-filled tank on a wooden-hulled vessel but, because the wooden hull interferes with the transmission of sound, a hole must be cut in it, so that the water in this tank is separated from the outside water by only a metal plate. On small vessels and launches the transmitting unit of a portable instrument is sometimes housed in a streamlined casing, known as a *fish*, which is secured in a submerged position alongside or over the bow of the vessel.

Electric energy is normally used to operate the transmitting unit, but mechanical energy is employed in some cases.

Transmitting units may be divided into four classes: (1) electromagnetic; (2) magnetostrictive; (3) piezoelectric; and (4) mechanical, that is, the hammer or striker type.

#### A. ELECTROMAGNETIC UNIT

The electromagnetic type of acoustic transmitter has a diaphragm, or emitting surface, actuated by the alternate attraction and repulsion of an electromagnet. The magnetic force may act directly on the diaphragm or be coupled to it through a system of levers. The diaphragm is sometimes tuned and in such case, when the frequency of the driving force corresponds to the natural frequency of the diaphragm, the amplitude of vibration of the latter is at a maximum and hence the maximum energy is transmitted to the water. Electric energy to actuate the electromagnetic transmitting unit is normally derived from some source of alternating current, such as a rotary generator. It is common practice to use an alternating current of half the frequency of the sound to be transmitted in the water. The frequency of vibration of the diaphragm of the transmitting unit will be doubled if there is no constant polarizing force to prevent the diaphragm from following each alternation of the electric current, irrespective of its direction. Electromagnetic transmitting units are generally used at sonic frequencies because of their greater efficiency at these frequencies.

#### B. MAGNETOSTRICTIVE UNIT

An increasing number of acoustic transmitting units utilize the magnetostrictive properties of certain metals and alloys in the production of supersonic signals. Certain metals change their linear dimensions when placed in an electromagnetic field. This property or phenomenon is called magneto-

striction. Where the magnetostrictive metal is in the field of a coil, should this coil be energized by an alternating electric current, the metal will alternately contract and expand along the axis of the coil in unison with the exciting current. Where this dimensional change is properly coupled to the water it will produce acoustic waves. Conversely, a fluctuating pressure applied to a face of the magnetostrictive material parallel to the magnetic field of the coil will cause changes in the field to produce an electromotive force across the terminals of the coil. Thus it is possible to use the same material for both the transmission and reception of acoustic waves. Commercially pure nickel, because of its high magnetostrictive property, its uniformity, and its chemical and mechanical stability, is most frequently used in this type of acoustic unit. Numerous methods, differing principally in coupling the vibrating unit to the water, are utilized to apply magnetostriction to the production of acoustic waves. In some types of transmitters the vibrations are coupled to the water by means of a diaphragm and in others the vibrating magnetostrictive elements are in direct contact with the water. The direct-contact units may utilize one surface of the magnetostrictive element in a manner similar to an oscillating piston, or the acoustic energy from the vibrating surface may be concentrated in the desired direction by the use of a reflector.

The exciting energy for the magnetostrictive element may be alternating current, normally generated by a vacuum-tube oscillator, but the method most frequently used involves the discharge of a previously charged condenser into the exciting coils, so that the magnetostrictive element is set into oscillation by the transient flux. This latter is known as shock excitation.

Magnetostriction finds its greatest application in echo sounding at supersonic frequencies. Figure 109 illustrates the assembly of a magnetostrictive unit which is described in detail in **5273**.

### C. PIEZOELECTRIC UNIT

Acoustic transmitting units that utilize the piezoelectric properties peculiar to certain crystalline substances are known as piezoelectric oscillators. Where such an oscillator is properly coupled to the water and excited, acoustic waves will be generated. Piezoelectric phenomena are exhibited by a

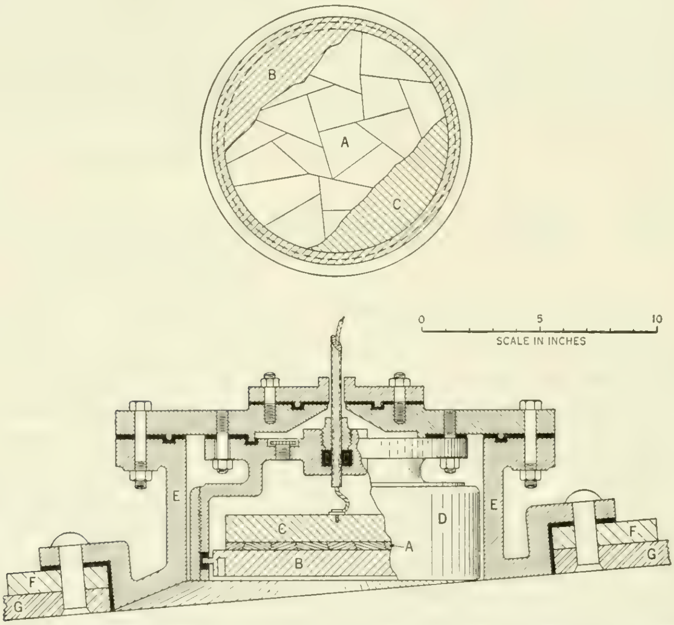


FIGURE 98.—Piezoelectric supersonic acoustic unit. *A*. Quartz crystals. *B*. Steel diaphragm. *C*. Steel plate. *D*. Housing. *E*. Hull mounting. *F*. Reinforcement ring. *G*. Hull plate.

number of crystalline substances. Those most frequently used for echo sounding are quartz and Rochelle salt, although others are sometimes used. Quartz has a higher mechanical and chemical stability, even though it may not be so piezoelectrically active as Rochelle salt. These crystals, where properly cut and ground, will show a physical strain and distortion when subjected to an

electric field and, conversely, will create an electric field when subjected to mechanical stress. It is this change of dimension, as in the magnetostrictive units, that is utilized for the production of acoustic waves.

Most echo-sounding transmitting units making use of the piezoelectric effect, one type of which is illustrated in figure 98, consist of a mosaic assembly of quartz crystals *A*, which are clamped between two metal plates *B* and *C*. The thickness of the assembly of crystals and plates determines the period at which the system will be resonant. One of these plates *B* is in direct contact with the water and forms the emitting surface. The energizing force to operate this unit is the electric field between the two metal plates. Electric energy to excite the piezoelectric oscillator may be from an alternating-current generator, but ordinarily excitation is produced by the high-frequency oscillations resulting from the discharge of a condenser into an electric circuit. Piezoelectric oscillators are generally used at supersonic frequencies, and may be used at frequencies much higher than is normally considered practicable for most other types of acoustic transmitting units.

#### D. HAMMER OR STRIKER TYPE

Impact sound producers, commonly known as hammer or striker types, generate a damped signal in the water. The essential operation is performed by a heavy metal plunger or hammer, forced by a compressed spring, which strikes a sharp blow against one side of a metal diaphragm, the other side of which is in direct contact with the water. The vibration of the diaphragm caused by the blow sends acoustic waves into the water. After the blow, the plunger is raised from the diaphragm by an electromagnet, the actuating spring being compressed during this operation. This leaves the plunger poised in position to repeat the cycle.

Instruments of the striker type are usually used only in moderate depths. Uncontrollable variations in the time of release and rate of fall of the impact plunger make this instrument unsatisfactory for use in accurate hydrographic surveys. As a navigation instrument, where reasonable accuracy is all that is necessary, its relative simplicity has contributed to its extensive use.

### *5162. Acoustic Receiving Units*

The purpose of the echo receiver, generally known as the hydrophone, is to take the acoustic energy of the echo from the medium and convert it efficiently into electric energy. Echo receivers are composed of two parts; the sound collector or diaphragm, and an element which converts acoustic energy to electric energy.

All echo receivers have their diaphragms or sound-collecting members submerged in water. This may be the water outside the ship's hull, or water in a tank contiguous to the inside skin of the ship. In the latter case the echo must penetrate through the hull plates to reach the receiver. The electroacoustic converter may be inside a watertight cavity closed by a diaphragm, or in direct contact with the water.

The type of echo receiver is usually determined by the frequency of the acoustic waves employed, whether sonic or supersonic. To receive sonic frequencies either a carbon button or an electromagnetic type of element is generally employed. Such elements are normally attached to the inner side of a diaphragm that closes a watertight cavity. The diaphragm may or may not be tuned to a definite frequency in water. The carbon-button element is often mounted in a watertight rubber jacket, which is submerged in a water-filled tank installed against the inside skin of the ship.

Supersonic frequencies are most commonly detected on magnetostrictive or piezoelectric receivers because of their more favorable response to these frequencies. Magnetostrictive receivers are either operated in conjunction with a tuned diaphragm or the magnetostrictive material is in direct contact with the water. Some piezoelectric receivers have the crystals sandwiched between two metal plates, one of which is in contact with the water. The plates and the crystals form an integral resonant unit which is tuned to the desired frequency.

TABLE 12.—*Acoustic transmitting and receiving units*

| Echo-sounding instrument | Transmitted signal frequency (in cycles) | Acoustic transmitting unit | | | Acoustic receiving unit | | |
|---|---|---|---|---|---|---|---|
| | | Type | Description | Mounting | Type | Description | Mounting |
| Dorsey Fathometer No. 1. | 17500 | Transceiver | Diaphragm type, magnetostrictive. | Diaphragm outside hull. | Same unit used for transmitting and receiving. | | |
| Dorsey Fathometer Nos. 2 and 3. | 17500 | do | do | do | Do. | | |
| | | | | | Tuned hydrophone No. 314A. | Tuned diaphragm, carbon button attached. | Inside tank. |
| | 1050 | 324 Oscillator | Tuned electromagnetic. | Diaphragm outside hull. | Watch case No. 134E. | Untuned diaphragm, carbon button attached. | Do. |
| | | | | | Rubber rat or K-tube unit. | Rubber jacket, housing carbon button. | Do. |
| 808 Recording Fathometer. | 20000 | Magnetostrictive | Rectangular stack of nickel laminations. | Inside fish | Magnetostrictive | Rectangular stack of nickel laminations. | Inside fish. |
| | | | | | Tuned hydrophone No. 314A. | Tuned diaphragm, carbon button attached. | Inside tank. |
| 312 Fathometer | 1050 | 324 Oscillator | Diaphragm type, electromagnetic. | Diaphragm outside hull. | Watch case No. 134E. | Untuned diaphragm, carbon button attached. | Do. |
| | | | | | Rubber rat or K-tube unit. | Rubber jacket, housing carbon button. | Do. |
| Hughes Veslekari | 16000 (approx.) | Magnetostrictive | Cylindrical stack of nickel laminations and conical reflectors. | Inside fish or tank | Magnetostrictive | Cylindrical stack of nickel laminations and conical reflectors. | Do. |
| Hughes MS 12 D | 16000 (approx.) | do | do | do | do | do | Do. |

Some echo receivers are constructed with frequency discrimination so they will respond only to the frequencies of the echo and be insensitive to noises of other frequencies.

The transmitting and echo-receiving units, used in conjunction with the various types of echo-sounding instruments of the Coast and Geodetic Survey, are listed in table 12.

### *5163. Echo Amplifiers*

When the echo receiver converts the acoustic energy to electric energy, the resulting amount is so small it must be increased to a usable value. This is one of the principal purposes of the echo amplifier. The desired amplification is obtained by the use of vacuum tubes similar to those used in radio receivers, the number and kinds of tubes used depending on the amplification required. In addition, this amplifier must possess other important characteristics, which may be listed as follows: (1) frequency discrimination; (2) stability; and (3) a small and constant time lag, or the property of passing the echo signal through the amplifier in a short and regular time interval.

Frequency discrimination is usually obtained by the use of highly resonant electric circuits which, by their filtering action, pass frequencies corresponding to the echo signal and attenuate spurious noises of other frequencies.

Apparent time lag through the echo amplifier is of minor consequence so long as it remains constant. Variations in the time lag may result in errors of serious magnitude, especially in shoal-water soundings. Instability in the amplifier is usually responsible for unpredictable changes in this lag. Gain-control variations also result in changes in the time lag, so it is important always to use high values of gain, since the variation in time lag is smaller for higher values of amplifier gain.

Most echo amplifiers are composed of a series of thermionic vacuum tubes with filters, tuned to the echo frequency, between the tube stages. Where high gain is needed a superheterodyne circuit is sometimes used. This type of circuit combines high gain with stability of an order which is difficult to obtain with single-frequency amplification.

### *5164. Registering Devices*

The purpose of the depth-registering device is to indicate visually, or record graphically, the depth of the water. All echo-sounding instruments operate on the same principle—by measuring the elapsed time between the emission of an acoustic signal and its return as an echo. The primary purpose of the registering device is to measure this time interval and convert it into some unit of linear distance (feet, fathoms, or meters).

Certain other parts are essential to the operation of the registering part of the equipment and will be considered as integral parts of the registering device. These essential parts are; the speed control of the driving motor, indication of motor speed, and the keying circuit that brings about the transmission of the acoustic signal.

Depth-registering devices are of two general types, the visual indicator and the graphic recorder.

#### A. VISUAL INDICATOR

A visual indicator usually consists of a scale graduated to read in units of depth and an index to indicate the measured depth on the scale. The type of visual indicator now most frequently used is a circular transparent depth scale, behind which the index revolves. The index is a slot cut in a disk, or radial arm, behind which a neon tube is placed so that its flash is visible adjacent to the depth scale. The neon tube is made to flash by the amplified energy resulting from the echo. Since the index travels around the scale at a known uniform rate of speed, the depth of water corresponding

to one revolution can be computed if the velocity of sound in sea water is known. With the depth scale appropriately graduated and the index revolving at normal speed, if a sound impulse is produced in the water just when the index is correctly referenced to the zero of the scale, then the position on the scale to which the index will have advanced, when the echo makes the neon tube flash, will indicate the depth. The index slot revolves continuously at a predetermined speed depending on the assumed velocity of sound for which the instrument is calibrated and the range chosen for the depth scale. A sounding is normally made once each revolution of the index, and where the instrument is designed for shoal sounding with a scale graduated to 20 fathoms, for instance, approximately 20 soundings will be obtained per second. In this case, because of the persistence of vision, the index will appear as a continuously illuminated line of light. For depth scales with greater ranges, where the index rotates more slowly, a succession of single flashes will appear at a point corresponding to the depth.

#### B. GRAPHIC RECORDER

Graphic-recording devices register depths by recording marks on a paper with or without a printed scale, at the beginning and end of a signal epoch. The record is made by a stylus that passes over the surface of the paper at a constant velocity, and marks permanently on it the times of transmission of the signals and reception of the echoes. The time intervals are measured either by a scale printed on the record paper or by reference to a scale held against the paper.

One of the principal problems in the development of recording instruments has been to find a suitable paper and method of recording the soundings thereon. At various stages of the development, methods involving all of the following have been used more or less successfully: smoked paper, wax-coated paper, ink and paint traces, charring or perforating the paper, and chemically treated paper. This last is used almost exclusively in European countries at present and is known as electrolytic record paper. In the United States a black-bodied paper is used whose surface is covered with a light-colored coating of special composition which disintegrates when an electric current is passed through it, exposing the black background at that point.

More detailed descriptions of graphic-recording devices are included in section **53**, and in **523**, **527**, and **528**.

### *5165. Motor Speed*

The accuracy of echo-sounding instruments is largely dependent on a constant and accurately known speed of revolution, either of the stylus of the graphic recorder or of the index of the visual indicator. In modern equipment this revolution is ordinarily produced by an electric motor whose speed is usually controlled within the limits of accuracy required.

*a. Centrifugal governor*—A centrifugal type of governor is commonly used for speed control. Electric contacts on the governor mechanism control the motor current in such a way as to compensate for any change of motor speed. Since a change of speed must occur before the governor can function, this type of control at best can only maintain the proper average speed, whose instantaneous rate is not known. However, a carefully designed and properly functioning governor will maintain a speed within such narrow limits as to give the accuracy required in most hydrographic surveys.

*b. Tuning-fork control.*—An alternating-current generator of constant frequency can be used to operate a synchronous motor at constant speed, and at the same time nearly eliminate instantaneous fluctuations of speed. Such generators, maintained at constant frequency by means of a tuning fork, are used in some types of echo-sounding equipment in conjunction with a synchronous motor. Where properly designed and operated in a stable electric circuit, the tuning fork will control continuously the frequency of an alternating current, essentially independent of changes in supply voltage, load torque, and temperature. This constant-frequency alternating current is then amplified and used to run a synchronous motor at a constant speed, regardless of load or friction. The increased precision resulting from the use of a synchronous motor controlled by a tuning fork, to drive the registering device, is especially valuable in hydrographic surveying. However, such synchronous-motor systems are more complicated than those that are governor-controlled and require the attention of trained personnel.

*c. Tachometers.*—A knowledge of the average motor speed is essential, especially where it is not adequately regulated or where only partly controlled. Tachometers of various types are the devices normally used to indicate motor speeds or motor-speed changes.

The Frahm type of tachometer consists of a series of metallic reeds, supported at one end and free to vibrate at the other, each having a natural period of vibration determined by its length and other physical properties. At its natural period a reed will vibrate at maximum amplitude. If there is a direct relation between the frequency of a reed and the motor speed at calibration velocity, the motor speed can be verified by observing the reed's amplitude of vibration—when it is a maximum it indicates that the motor is operating at the correct speed. A reed tachometer is usually composed of seven reeds, ranging by a few percent above and below the calibration velocity, which is indicated on the middle reed. The reeds of higher and lower frequency serve to indicate the amount and direction of the motor-speed deviation. The reed tachometer is usually operated by some unbalanced mechanical force, or is actuated by an electromagnet that receives impulses from a commutator coupled to the indicator motor. (See **5234**.)

When alternating current is used to drive the indicator motor a frequency meter calibrated in revolutions per minute is sometimes used.

## 52. ECHO-SOUNDING INSTRUMENTS USED BY THE COAST AND GEODETIC SURVEY

The Coast and Geodetic Survey uses a number of different echo-sounding instruments, sometimes several on one vessel, depending on the nature of the surveys expected to be made. For surveying in deep water, such instruments as the Dorsey Fathometer Nos. 2 and 3, the 312 Fathometer, and the Veslekari Recorder are used. For a vessel used principally for surveying in shoal to moderate depths, the sounding equipment normally includes a Dorsey Fathometer No. 1 or a permanently installed 808 Fathometer. Since the range of the Dorsey Fathometer No. 3 includes both shoal and deep water, and since this instrument embodies all the principles and accuracy of the Dorsey No. 1, there is no need for a special shoal-water instrument on a survey vessel equipped with a Dorsey No. 3.

Some vessels are equipped with two or more instruments so that, if the principal instrument fails to function, another may be substituted immediately. Furthermore, the availability of two or more instruments permits the use of the particular instrument best suited for the depths and character of the bottom at the time. The advantages of two instruments on a vessel are further discussed in **545**.

Besides those instruments mentioned above, a large number of semiportable graphic recorders are now being used by the Coast and Geodetic Survey for surveys in shoal water. Because of their portability they may be transferred from one vessel or field party to another as the need arises.

All of the instruments in use in 1941 are described in this section. Because of the constant progress and development of echo sounding it must be expected, however, that other types of instruments will be in use, perhaps in the near future.

### 521. 312 FATHOMETER

The 312 Fathometer may be classified as a visual, sonic type, echo-sounding instrument intended for depth measurements in water ranging from moderately shoal to deep. This instrument is manufactured by the Submarine Signal Company of Boston, Massachusetts, and has been used by the Coast and Geodetic Survey since 1925, and is still used for surveys in deep water on a number of the vessels of the Bureau. The optimum depth range of the 312 Fathometer is from 20 to 4,000 fathoms, although it has been used in depths as shoal as 12 fathoms with very good results. In actual use the range will vary, depending on the installation, the vessel, and other conditions affecting echo sounding. The maximum range of 4,000 fathoms is obtained only from a perfect installation and under the most favorable echo-sounding conditions.

Early models of the 312 Fathometer were calibrated for a velocity of sound in water of 800 fathoms per second, but later models have been calibrated for a velocity of 820 fathoms per second. Most of the instruments now used by the Coast and Geodetic Survey are calibrated for 820 fathoms per second.

The 312 Fathometer is composed of five separate pieces of equipment: (1) a transmitting unit, or oscillator; (2) a d-c to 525-cycle a-c motor generator; (3) an echo receiver, or hydrophone; (4) an echo amplifier; and (5) a visual indicator. All of these units are interconnected so that each performs its important function in relation to the entire operation of the instrument.

Briefly, the operation of this Fathometer in measuring depths is as follows: An electric contact made by an eccentric on the index shaft, at a predetermined position of the index relative to the depth scale, energizes the oscillator for a few thousandths of a second, causing it to emit a train of sound waves of a given frequency in the water. The echo from the transmitted sound energizes the echo receiver and is amplified by the echo amplifier. The output voltage of the echo amplifier is sufficient to flash a neon tube behind the revolving index slit of the visual indicator. The sounding is read from the depth scale at the place where the neon tube is seen to flash.

### *5211. Oscillator*

The acoustic transmitting unit, or 324 oscillator, which produces the sound in the water, is of the electromagnetic type. An assembled and an unassembled view of this

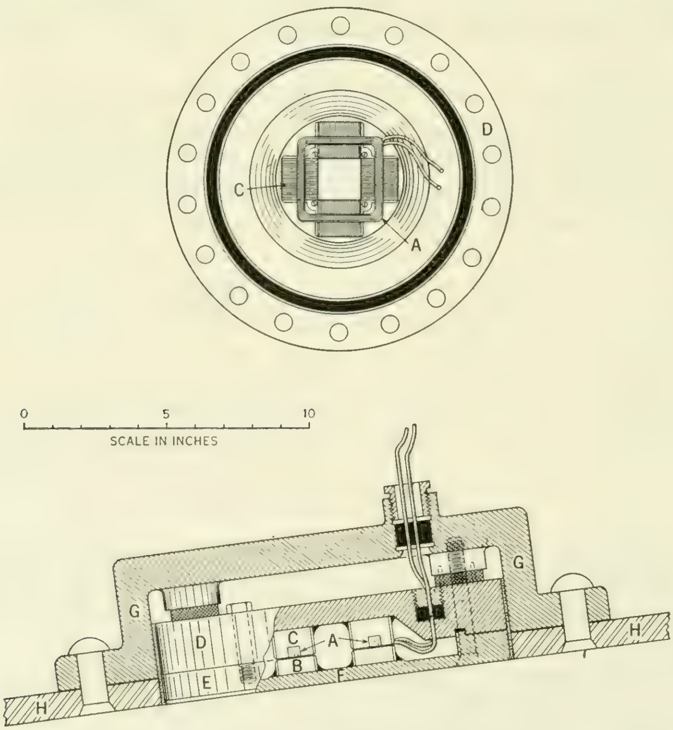


FIGURE 99.—Electromagnetic oscillator type 324. *A*. Exciting coil. *B* and *C*. Steel laminations. *D* and *E*. Upper and lower sections of housing. *F*. Stainless steel diaphragm. *G*. Hull mounting. *H*. Hull plate.

oscillator are shown in figure 99. The diaphragm *F* is 13 inches in diameter and is made of stainless steel. By proper dimensioning, the diaphragm is given a natural

frequency of 1050 cycles per second in water. Welded to the inside center of the diaphragm is a group of steel laminations *B* and opposite to these a corresponding group *C* is welded to the housing. A coil *A* is wound around the latter group of laminations to carry the exciting current. The vibrational frequency of the diaphragm is twice that of the exciting current since no polarizing force is used on the diaphragm, and it follows the alternations of the exciting current, regardless of direction of flow, to produce a sound in the water of 1050 cycles. The outer face of the diaphragm must be in direct contact with the water, so the oscillator must be mounted in an opening cut in the bottom of the vessel.

### *5212. Motor Generator*

Energy to excite the 324 oscillator is supplied by a motor generator, which is operated from the ship's 110-volt d-c power circuit, and which produces 125 volts at 525 cycles. It has a rating of 500 volt-amperes. A tuning condenser in series with the generator and oscillator gives unity power factor at 525 cycles, producing maximum energy transfer. The generator speed, and hence the output frequency, tends to vary, but is controlled by a motor-field rheostat. This rheostat and a frequency meter calibrated from 500 to 600 cycles are located near the depth indicator so that the frequency can conveniently be kept at 525 cycles, or half the fixed frequency of the oscillator.

The 525-cycle motor generators of later model 312 Fathometers have been equipped with governors, to keep the no-load and full-load speeds of the machine nearly constant. This keeps the frequency of the generator more nearly in its proper relation with the tuned circuits of the 324 oscillator during the keying period. More sound energy at 1050 cycles is transmitted by this arrangement, and the returning echo will be of greater intensity.

This increase in sound energy may cause excessive reverberation in vessels of certain design, resulting in an apparent prolongation of the initial signal. This may seriously interfere with sounding in shoal to moderately deep water, but it may be effectively damped by placing heavy weights around the oscillator, and sometimes around the hydrophone tanks. On one vessel where reverberation was bothersome 14,000 pounds of pig lead were evenly distributed in the frame spaces surrounding the oscillator, and 3,000 pounds were placed around the hydrophone tanks.

### *5213. Hydrophone*

The echo receiver, or hydrophone, used to detect the echo and convert its sound energy into electric energy may be one of several types, depending principally on the depths being sounded. Two or more different types of hydrophones are commonly employed so that any one can be switched into operation for use in those depths where it gives optimum results. The three types of hydrophones commonly used with the 312 Fathometer are:

(*a*) Tuned hydrophone No. 314*A* is a large brass unit whose diaphragm is tuned to respond best at frequencies of 1050 cycles in water. This hydrophone is generally used for deep-water soundings.

(*b*) The K-tube unit, a rubber-cased hydrophone, also known as the rubber rat, employed principally in shoal and moderately deep water.

(*c*) Hydrophone No. 134*E* is a small brass unit, sometimes known as the watch-case unit, used for shoal and moderately deep soundings.

Each of these units is installed in a water-filled tank secured to the inside skin of the ship. The electroacoustic element of each of these hydrophones is a carbon button fastened to the inside of the diaphragm.

### *5214. Echo Amplifier*

Numerous changes have been made to the echo amplifiers to take advantage of recent improvements in tubes and circuits, with the result that no two 312 Fathometer echo amplifiers in use on vessels of the Coast and Geodetic Survey are the same. They differ principally in the number and kinds of tubes and the source of power used to operate the amplifier. The power source may be the ship's 110-volt d-c current, batteries, or rectified alternating current. Iron-core transformers are normally used to form the coupling between tubes. The gain control of the echo amplifier is generally on or near the indicator, so that sensitivity adjustments can be made while viewing the depth scale of the indicator. A band-pass filter, tuned to 1050 cycles, is sometimes used in conjunction with the amplifier to aid in discriminating against spurious noises. The output voltage of the echo amplifier is used to excite the grid of a gas discharge tube, whose discharge flashes neon tubes in the indicator.

### *5215. Indicator*

The visual indicating mechanism of the 312 Fathometer is housed in a metal cabinet whose outside dimensions are 13 by 15 by 11½ inches. In the front of the cabinet is a circular hole, 11 inches in diameter, fitted with a glass on which are two concentric circular scales. The inner one is graduated in fathoms, from 5 to 100 fathoms; and the outer one in 5-fathom intervals, from 0 to 600 fathoms. A motor-speed indicator, a start-and-stop switch, and two adjustment knobs are also installed in the front of the cabinet. A reed tachometer is used to indicate the amount and direction of motor-speed deviation (see **5234**). The left-hand adjustment knob is for manual control of the motor speed for line-voltage changes beyond the limit of the governor. The right-hand knob is the sensitivity adjustment and controls the current flowing in the carbon button of the hydrophone. On the left side of the cabinet is a gearshift knob for changing the disk speed to correspond to one of the two depth scales. On the right side of the cabinet is a push button by which the transmission of the signals may be stopped, as desired. The important parts contained in the cabinet are: the indicator motor and governor, the reed tachometer, reduction gears, gearshift mechanism, rotating disk that carries the neon tubes, and the keying cam and contactors.

A 110-volt d-c, $\frac{1}{20}$-horsepower motor, operated at 1,800 r.p.m., is used to revolve the index disk and operate the keying cam. It is important, for the sake of accuracy, that the speed of this motor be maintained constant. A centrifugal governor is used to control the speed for changes in torque and line-voltage variations between 90 and 115 volts.

The motor speed is reduced by means of gears to the proper speed of the index disk. The speed ratio may be changed by means of a gearshift mechanism, so that the index disk will rotate at either 4.1 r.p.s. or 0.683 r.p.s. for soundings on the 100- or 600-fathom scale respectively.

The index disk, of thin bakelite, is circular in shape, its diameter being a little less than the circular opening in the face of the cabinet. Attached to the back of the disk, and rotating with it, are two small U-shaped neon tubes. Electric connections are made to these tubes by means of slip rings. The index, one for each tube, is a narrow slit, cut in the disk, through which the light is seen when the tube flashes so that the position of the index relative to the depth scale may be read. The neon tube that operates with the 100-fathom depth scale is installed so that it can be rotated with reference to the disk through an arc equivalent to 7 fathoms, to adjust for the mean depth of the

oscillator and hydrophone below the surface of the water. When the 100-fathom scale is used in sounding, the neon tube for that scale rotates at 4.1 r.p.s. This neon tube is electrically connected through a switch to the output of the gas discharge tube. When a change is made from one speed to the other, the gearshift mechanism, in addition to changing the speed of the index disk, switches the gas discharge tube circuit from one neon tube to the other.

Signals are normally sent once each revolution of the index by closing the electric circuit through the 525-cycle generator and the 1050-cycle oscillator. This is done by means of a dog mounted on the shaft which rotates the index disk. The dog is adjustable circumferentially so that the time of starting the signal may be controlled.

Echoes received on the 100-fathom scale near 100 fathoms (which is also the zero of the scale) are difficult to distinguish from the transmitted signals. By transmitting a signal only every alternate revolution this difficulty is overcome, and the echo and transmitted signal are seen alternately. The circuit by which every alternate signal is deleted is called the *100-fathom cutout.* It consists of a wheel that rotates at half the speed of the disk, which has metal and insulating segments so arranged that the brushes which contact it complete an electric circuit once every alternate revolution of the disk. The keying contactors and the 100-fathom cutout circuit are electrically connected in series so that current can flow through the series combination only once each alternate revolution of the disk. The 100-fathom cutout is switched into or out of operation by means of a toggle switch on the underside of the cabinet. A cutout on the right side of the cabinet may be operated manually for the same purpose. This latter cutout is utilized when depths of 200 or multiples thereof are received on the 100-fathom scale. And it may be used with both the 100- and 600-fathom scales.

### *5216. Operation*

To operate the 312 Fathometer for sounding, the starting switch is closed, and a period of a few seconds is allowed for the motor to come to operating speed. By the frequency-control rheostat the frequency is adjusted to 525 cycles, or some value near this which has been found to give optimum results. The hydrophone current is then adjusted by means of the right-hand knob, so that it is from 1 to 5 milliamperes. The gain control of the amplifier is adjusted for optimum operation (see **5163**). The motor speed should be adjusted so that the middle reed of the tachometer is vibrating at maximum amplitude. The instrument is now ready for sounding on the scale selected in accordance with the depth of the water.

## 522. SIMPLEX-BLUDWORTH

The Simplex-Bludworth Fathometer, Model *ES*–104, is manufactured by National Simplex-Bludworth, Incorporated, of New York City. It is a semiportable, supersonic, graphic-recording, echo-sounding instrument designed for surveys in shallow to moderately deep water and for temporary installation in a launch or vessel. It is an instrument of the same general type as the 808 Fathometer and is similar to it in many respects (see **523**). This is the most recently acquired echo-sounding instrument of the Coast and Geodetic Survey and has not yet been tested in the field. It is only briefly described here, mainly for the purpose of pointing out those features that distinguish it from the 808 Fathometer. The fact should be noted that it was not available when other parts of chapter 5 of this Manual were written.

### *5221. Description*

The Simplex-Bludworth Fathometer consists essentially of three separate units: a recorder cabinet containing the graphic-recording mechanism, signal sender, echo amplifier, and speed indicator; a submersible unit consisting of a streamlined cast-aluminum housing which contains the transmitting and receiving oscillators; and a 12-volt storage battery. For proper operation, the units should be located according to the instructions given for the 808 Fathometer (see **5236**).

*a. Recorder cabinet.*—All essential parts except the transmitting and receiving units and the battery are in one metal case which has a canvas cover for protection from the weather. The operating controls, all conveniently located, consist of an on-off power switch, an on-off recorder switch, a phase-changing control, a "foot-fathom" selector switch, a sensitivity control, a fix-marker button, and a control for compensating for draft or tide. There are also a motor-speed meter and a reed tachometer. All of the controls and meters are located on the top of the case or are accessible through it when the case is closed. The top of the case also contains glass ports through which the draft setting can be verified and the fathogram viewed.

The recording mechanism consists of a revolving drum coupled directly to the motor shaft clutch for recording in feet and reduced through a 1 to 6 gear ratio for recording in fathoms. The 12-volt d-c driving motor has a speed range from 2,280 to 2,580 r. p. m., with 2,460 corresponding to a velocity of sound of 820 fathoms per second. The electric impulse, which makes the depth record, is transmitted through a raised wire set into a helical groove in the drum. A printer blade is mounted in a bridge directly above the revolving drum and is adjustable in the bridge so that a uniform pressure can be maintained on the record paper where it contacts the helical wire.

The record paper is of the dry facsimile type, impregnated with conductive material and surface-coated with an electrosensitive substance. The paper is rove between the revolving drum and the printer blade so that when an electric impulse is received it passes from the printer blade through the paper to the helical wire, leaving a permanent black mark at the point of contact of the blade and wire. The paper has a continuous printed scale which is 6½ inches wide, the width being divided by lines into 60 equal parts, each part representing 1 foot or 1 fathom depending on which operating speed is used; and perpendicular to these lines are travel-spacing lines 1 inch apart. A depth range to 180 feet (or fathoms) is provided by three phases as follows: 0 to 60, 60 to 120, and 120 to 180, a scale for each phase being printed in different color and style numerals alternately along the paper at 2-inch intervals, each scale being repeated every 6 inches. When the instrument is recording in feet, the travel speed of the paper is 2 inches per minute at a motor speed of 2,460 r. p. m. The paper travel is provided by positive rubber friction rollers and the paper is truly alined by means of limiting rollers.

The signal sender in the recorder cabinet energizes electrically the transmitting oscillator. The sender operates from a 350-volt vibrator-type power supply, and when keyed produces an electric impulse in the oscillator in exact synchronism with the keying commutator.

The echo amplifier is a three-stage resistance-coupled thermionic type, tuned to respond at maximum sensitivity at a frequency of 14250 cycles per second. The input stage is transformer coupled to the receiving oscillator and the output stage is transformer coupled to the printer blade.

*b. Submersible unit.*—The submersible unit consists of a transmitting and a receiving oscillator mounted in a streamlined cast aluminum housing 37 inches long by 14 inches wide; the oscillator centers are 13 inches apart; the units are very similar to those of the Hughes *MS* 12 *D* (see **528** and **5273**). The magnetostrictive oscillators consist of packs of thin annular nickel stampings mounted on a spindle inside an air-filled reflector and immersed in castor oil. Each pack is toroidally wound with an energizing coil of neoprene insulated wire.

The operating frequency of the oscillators is 14250 cycles per second and is outside the normal range of interference from ordinary water noises. The transmitting and receiving oscillators are identical in all respects except that the receiving unit is permanently magnetized.

The submersible unit should be installed so that its bottom is at least 2 feet below the surface and in a horizontal plane, and its axis parallel with the centerline of the vessel. There should be at least a 1-foot clearance between it and the vessel.

### 5222. Operation

The revolving drum is the time measuring device on this Fathometer. An auxiliary keying shaft is driven through a 1 to 4 gear ratio from the drum shaft so that a keying cycle occurs at every fourth revolution of the drum. Soundings in feet are therefore recorded at the rate of 615 per minute and in fathoms at 102.5 per minute for a motor speed of 2,460 r. p. m.

At the correct instant of each fourth revolution of the drum, the signal sender, to which it is keyed, sends an electric impulse to the transmitting oscillator, causing the magnetostrictive unit to transmit a supersonic signal of a frequency of 14250 cycles per second. The echo is received on the receiving oscillator and amplified by the echo amplifier, the resulting current passing to the printer blade and through the record paper at the point where the blade is in contact with the helical wire on the revolving drum, leaving a permanent black mark on the paper. The arrangement of the wire on the drum is such that at any instant the printer blade can be in contact with the helical wire at one point only, and the revolution of the drum thus becomes a measure of the elapsed time between the transmission and reception of the sound signal.

*a. Draft adjustment.*—The adjustment for the depth of the oscillators below the surface of the water is made with reference to a scale with a range from plus 10 to minus 5 feet. The adjustment for draft must always be made on the 0 to 10 part of the scale. Any adjustments made with reference to this scale in feet are correctly applied to the fathogram irrespective of whether the soundings are recorded in feet or fathoms. When the adjustment is set at zero, the instant of transmission coincides with the zero of the record paper, but the recorded depths are all referred to the plane of the oscillators. When the adjustment is set on the 0 to 10 part of the scale, the instant of transmission is delayed to account for the draft of the oscillators.

The draft adjustment scale can also be used for mechanically applying other various corrections involved in echo sounding, such as instrumental error (**552**), settlement and squat (**553**), and, under certain conditions, tide (**56**).

*b. Motor speed adjustment.*—The speed of the driving motor is controlled by a centrifugal governor which can be manually adjusted by turning a knob on the end of the case.

A meter calibrated in motor revolutions per minute and also a reed tachometer (see **5234**) are provided for verifying the motor speed. The middle reed of the tachometer vibrates at maximum amplitude when the motor speed is 2,460 r. p. m., which corresponds to a velocity of sound in water of 820 fathoms per second. The reed tachometer is more accurate than the meter. The instrument will accommodate a velocity of sound range from 760 to 880 fathoms per second.

Since the calibration velocity of an echo-sounding instrument is a function of the motor speed (see **555**), the instrument can be adjusted, under certain conditions, to record soundings based on the actual velocity of sound in the area.

A book is provided which contains instructions relative to maintenance, service, operating difficulties, circuit tests, and tables of correct voltages and resistances, and lists spare parts by number.

### 5223. Comparison With 808 Fathometer

The following are, in summary, the outstanding features of the Simplex-Bludworth Fathometer that are not possessed by the 808 Fathometer:

(1) A draft adjustment scale.

(2) An indication of driving motor speed so that adjustments may be made to account for the actual velocity of sound at the time of making the survey.

(3) The record is made along a straight-edged stationary bar giving a straight line record on paper with rectangular coordinates, eliminating contraction of the scale near the paper edges.

(4) The paper is held in true alinement with limiting rollers, thus avoiding the disadvantages of perforations.

### 523. 808 FATHOMETER

The 808 Fathometer is a semiportable, supersonic, graphic-recording, echo-sounding instrument designed for hydrographic surveying in shallow to moderately deep water from small vessels and launches. Its range is from ½ foot below the *fish* to 160 fathoms. This instrument is manufactured by the Submarine Signal Company of Boston, Massachusetts, from specifications prepared by the Coast and Geodetic Survey. Prior to the introduction of the 808 Fathometer, soundings had been taken from small boats and launches of the Coast and Geodetic Survey by using the leadline and wire sounding machines. These methods were slow and at times inaccurate.

FIGURE 100.—Launch hydrography using the 808 Fathometer.

The salient features of the 808 Fathometer are:

(*a*) It is a semiportable instrument that can be installed in any small boat without the necessity of cutting an opening in the hull, and without any complicated wiring or any of the other complications of a permanent installation.

(*b*) The instrument may be permanently installed in any vessel by housing the transmitting and receiving units properly inside the hull.

(*c*) The practical depth range is from the least depth in which the vessel or launch will float to 160 fathoms under proper conditions.

(*d*) Soundings may be recorded in feet or fathoms to accommodate the depth range and the types of submarine relief encountered.

(*e*) The range of the scale of the record paper is 55 divisions (feet or fathoms), and by means of a phasing arrangement three other ranges may be recorded on the same scale, thus providing for an expanded scale covering a depth range of 0 to 160 (feet or fathoms).

(*f*) A fast paper travel (about 2 inches per minute when recording in feet) to give a detailed record

(*g*) The use of a facsimile paper with printed depth scales for graphic recording. The paper does not have to be moistened or chemically treated before or afterward, thus avoiding dimensional change.

(*h*) A fix marker by which any event (e. g., a sextant fix) may be recorded on the fathogram.
(*i*) Supersonic magnetostrictive transmitting and receiving units.
(*j*) A single 12-volt storage battery supplies all necessary power.

The 808 Fathometer is composed of three separate units: a streamlined submersible housing (called the *fish*) containing the acoustic transmitting and receiving units; a recorder cabinet containing the graphic-recording mechanism, keying mechanism, and the echo amplifier; and a 12-volt storage battery. All these units can be installed in or removed from a launch equipped for them in a short time at the beginning or end of the working day. The fish is secured over the side of the launch; the recorder cabinet is secured to a thwart or bulkhead in some protected part in the launch; and the batteries should be installed in a specially prepared wooden box lined with sheet lead.

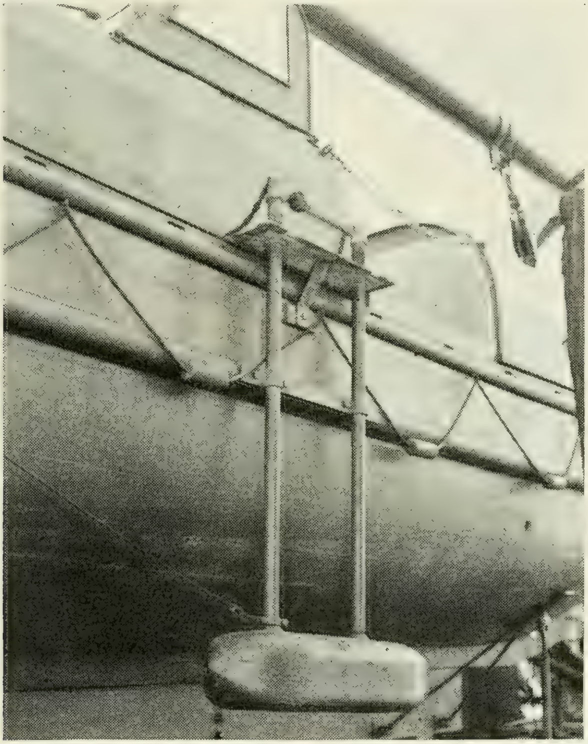

FIGURE 101.—Fish of 808 Fathometer mounted on hydrographic launch.

### *5231. Acoustic Transmitting and Receiving Units*

The *fish* is a mahogany casing about 30 inches long by 8 inches square, projectile-shaped at the ends to ensure nearly streamlined motion through the water. The weight of the fish is about 80 pounds out of water and 30 pounds when submerged. A portion of the bottom of the fish is hollowed out and a brass casting inserted to support the magnetostrictive transmitting and receiving units. The underside of the casting is closed by two thin metal plates, through which small holes have been punched to allow the cavity containing the transmitting and receiving units to fill with water. The units are identical, each consisting of a bundle of rectangular nickel laminations. Each unit is approximately 6 by 4 by 3⅜ inches in size. Each lamination is approximately 4 by 3⅜ inches by a few thousandths of an inch thick. Three rectangular openings are

punched in the laminations which, when assembled, resemble a transformer core. A few turns of rubber-covered wire are wound through the openings in such a way as to include most of the nickel in the field of the windings. The cores are so dimensioned that the entire unit has a natural frequency of vibration in water of 20 kilocycles. The units are installed so the 4-inch dimension is vertical and the vibration of the horizontal face of the transmitting unit, by the magnetostriction phenomenon, projects a beam of supersonic sound downward into the water.

The receiving unit is aft of the transmitting unit in the fish. The two units are identical in every respect and may be used interchangeably. The separation between the units is only 9 inches, thus practically eliminating any error due to separation (see **556**), even for measurements of very shoal depths.

The cables from the two units are led through two pipe fittings at the top of the brass casting, and thence pass through two pipes that are screwed into these fittings to form part of the supporting structure for the fish. These are rubber-covered, two-conductor cables, covered with a flexible woven metal shield. The cable ends are provided with plugs by which they are connected to the recorder cabinet.

### *5232. Recorder Cabinet*

The recording mechanism is housed in a cabinet 21 inches long by 17 inches wide by 10 inches high; the cabinet is an aluminum casting, with a glossy black finish. This cabinet contains the entire recording apparatus, paper, echo amplifier, and phasing and keying circuits. The total weight of the cabinet and all contents is 103 pounds. The cabinet may be mounted on a vertical bulkhead or panel, or placed face up on deck or on a table. The main door of the cabinet is hinged on the left, as one faces it, and accordingly opens from right to left. This door is secured by two large wing nuts on the right side. A small glass door in the main door covers the record paper and exposes about 2½ inches of the fathogram before it is automatically wound on a take-up spool at the right. Looking at the record in this position, with paper moving toward the right, the profile of the bottom is disclosed in its natural position, that is, with the zero line, or sea surface, at the top of the record.

This cabinet is sprayproof and the instrument is designed to be operated in rather severe weather, without harm to paper or mechanism. The glass door, through which the fathogram is viewed, may be raised to permit access to the fathogram for making notations thereon, either with black or colored pencil, or with a fountain pen. An exhaust fan mounted in the cabinet removes the carbon dust formed on the paper and dissipates any heat in the cabinet.

Controls and other devices located on the front of the panel are: the phasing dial, an index-adjuster knob, a gearshift for changing from feet to fathoms or vice versa, a reed tachometer, a governor adjuster, an amplifier sensitivity control, a 0- to 15-volt d-c voltmeter, a fix-marker button, and a switch to turn on the electric bulbs which illuminate the fathogram. On one side of the recorder cabinet is an off-on switch and two manual motor-speed controls, one for rough and the other for fine adjustment. On the left end of the recorder cabinet is a toggle switch by which the mark made on the fathogram by the transmitted signal may be greatly reduced in intensity. The three receptacles, into which the leads from the battery and transmitting and receiving units are plugged, are on this same end.

The important parts contained in the recorder cabinet are: the driving motor and governor, recording mechanism, keying circuit, phasing mechanism, two motor generators, and the echo amplifier.

Part of the moving mechanism, consisting of the driving motor, governor, gear box, rotating stylus arm, and contactor, is mounted on the inner side of the door of the cabinet. The two motor generators are mounted in the bottom of the cabinet; one supplies 300 volts for part of the plate power of the amplifier; the output tubes, however, being supplied by a 350-volt generator which also actuates the transmitting unit. The driving motor operates a train of gears to rotate the stylus arm and to operate the contactor 11.18 times per second for sounding in feet, and at one-sixth that speed for sounding in fathoms, or 123 revolutions in 66 seconds. The rotating arm is 4.5 inches long and carries at its end a stylus of fine piano wire, which sweeps in an arc across the fathogram paper. A condenser is charged continuously through a resistor by the 350 volts from the motor generator. Once each revolution, contactors are closed by the rotating arm, normally at the instant the steel stylus wire passes a point on the fathogram scale corresponding to the depth of the fish below the water surface. These contactors discharge the condenser into the magnetostrictive transmitter, producing a short pulse of vibrations at the rate of 20,000 per second, and thus the signal is sent.

There are two ways by which the position of the contactors in the cycle of rotation may be changed with reference to the zero of the fathogram scale. Small adjustments may be easily and quickly made, by means of a knurled knob, while the machine is running, so that the transmitted signal is made to record at exactly zero, or if desired, at a depth corresponding to the draft of the fish, thereby referring all recorded depths to the water surface.

The position of the contactors is also changed when the phase is changed. The printed scale of the fathogram reads from 0 to 55—feet at high speed (11.18 soundings per second) or fathoms at slow speed. However, if the contactors are advanced, opposite to the direction of rotation, so that the signal is emitted the equivalent of 35 feet (or fathoms) before the stylus reaches the zero of the fathogram scale, the scale will then record depths from 35 to 90 feet (or fathoms). Advancing the contactors in this way is called *phasing*. It is accomplished simply by lifting a little knob on the face of the recorder and turning an arm to the phase desired. This knob has a plunger which drops into a hole to maintain the contactors at exact position for each phase.

There are four phases in all, 0 to 55, 35 to 90, 70 to 125, and 105 to 160 feet (or fathoms), each phase overlapping the preceding one by 20 feet (or fathoms) so that no soundings need be missed when changing from one phase to another. The shift in phase can be made quickly, in either direction. The transmitted signal is recorded on the fathogram on the first phase only, the 0 to 55 scale. Even then its recorded intensity may be greatly reduced by turning a switch, so that it will not interfere with the record of extremely shoal depths; for example, depths less than 3 feet under the *fish*.

The magnetostrictive receiver is connected to the echo amplifier, located inside the recorder cabinet. The amplifier is a three-stage, tuned, push-pull type, completely shielded, containing six tubes having their 6-volt heaters grouped in three pairs in series on the 12-volt storage battery. With maximum gain the amplifier sensitivity is 0.2 microvolt. A graduated gain-control knob is located on the front of the cabinet door. The echo is amplified until the third pair of tubes develops about 180 volts across an output transformer. This voltage is applied between the stylus and the metal platen under the paper so that a series of sparks of diminishing intensity pass through the paper at the time the signal is sent, and upon reception of the echo. These sparks remove the gray coating leaving the black paper visible, as though a series of closely spaced

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black dots had been made on the gray surface. The dots are scarcely distinguishable as such unless magnified and consequently the record appears as a rather broad band with more or less sharp and smooth contour at the top, the bottom of the band fading away gradually. The intensity of the record is somewhat proportional to the strength of the echo. Figure 102 is a schematic wiring diagram of the amplifier and all other electric connections.

### *5233. Fathogram*

The graphic record of an echo-sounding instrument is called a fathogram. The paper on which this is recorded on the 808 Fathometer is a standard type used for facsimile reproduction. It has a black body coated a light gray on its upper surface, the reverse side being metalized with aluminum or copper for the purpose of electric contact. The paper is 7 inches wide and comes in 75-foot rolls on metal spools. The printed scale is 6¼ inches wide, ruled horizontally into 55 divisions, each representing 1 foot or 1 fathom, depending on which operating speed is used. Since the scale of equal divisions lies along the arc of a circle traversed by the rotating stylus, the horizontal graduations are closer together near the edges of the paper, but the distance between lines, measured along the arc, is ⅛ inch. The division lines are printed in red, and four numerical scales of depth, 0 to 55, 35 to 90, 70 to 125, and 105 to 160, are printed alternately in red and green on the gray surface. The numerals corresponding to the 0 to 55 scale are printed in large red figures, those for the 35 to 90 scale in large green figures, those for the 70 to 125 scale in small red figures, and those for the 105 to 160 scale in small green figures. The four phases are indicated by the letters **A**, **B**, **C**, and **D** respectively, and at the shoal end of each scale the letter corresponding to the respective phase is printed in color and size corresponding to the numerals of the scale. The numerical scales are spaced about 1¼ inches apart and are repeated in the above sequence. Regardless of which phase is being used, a corresponding numerical scale will always be within 2½ inches of any point of the record, facilitating easy reading. While the fathogram is being recorded, the corresponding numerical scale will not always be visible, however, since only about 2½ inches of it is visible at a time. A notation of the phase in use must be made on the fathogram at the time. Depths recorded in fathoms are generally distinguishable from those in feet, the former usually being blacker and the trace of the stylus, along its natural arc, shorter.

The travel speed of the fathogram paper under the stylus is 2 inches per minute when recording in feet. Thus a 75-foot roll of paper will last 7½ hours when sounding in feet, or 45 hours when sounding in fathoms.

Unlike some types, this paper is used dry, requiring no treatment before or after recording. The new roll is installed in a holder beneath the stylus arm, whence the fathogram paper passes to the right across the recorder platen to an automatic take-up spool. These roll holders are secured to the inside of the cabinet door and are readily accessible when the door is opened.

Neither excessive heat nor humidity materially affects the dimensions or the color of the paper. Aging tests show that the quality of the paper and the permanence of the record are satisfactory. Tests were made to determine the dimensional change in the paper with variations in humidity. From very dry to normal humidity the change in width was 0.6 mm; from dry to saturation by steam it was 1.5 mm. In terms of the fathogram scale this would mean a maximum of 0.5 foot in 55 feet, or 0.5 fathom in 55 fathoms, or slightly less than 1 percent change, under extremes probably never encountered in practice.

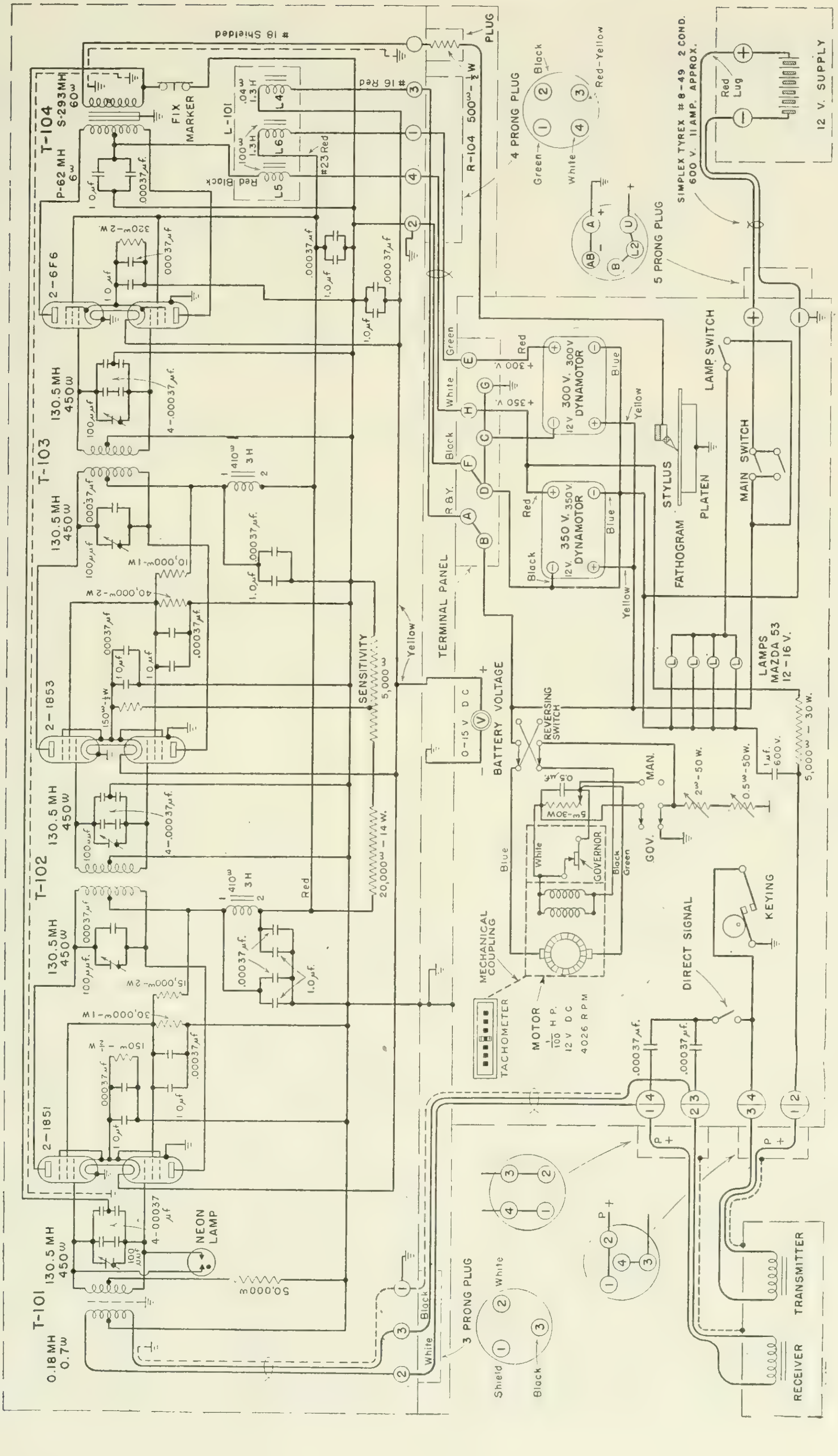


FIGURE 102.—Circuit diagram of 808 Fathometer.

Carbon rubs off the record to such a degree that objects with which it comes in contact, or one's hands, are soiled.

Holes a half-inch apart are punched along both edges of the paper. The holes along the top are circular, while those along the bottom edge are elongated. These holes engage the teeth of the sprocket roller whose purpose is to move the paper across the recorder platen. This sprocket roller is driven by a shaft directly geared to the same motor that rotates the stylus arm. It is impossible for this roller to rotate, and thus for the paper to travel, slower than at the correct proportional speed.

However, the sprocket roller is free to rotate around the shaft at a faster speed than the correct one. The take-up roller is driven from the sprocket-roller shaft by a coil-spring belt so adjusted that it will slip. If this adjustment is so tight that it does not slip as intended, the paper can be drawn across the platen by the take-up roller instead of by the sprocket roller, in which case the paper travel is at too fast a speed.

The paper must lie flat on the platen, and must be properly centered so that the teeth of the sprocket roller engage the holes cleanly, without mutilating the holes. When a new roll of paper is placed on the instrument it may be necessary to adjust the take-up roll, or the feed roll, or both. This adjustment is accomplished by first loosening the locknut on the end of each roller and then turning the adjustment knob until the paper is properly alined, after which the locknut is tightened. When the paper is properly adjusted, arcs drawn by the stylus should correspond with the printed arcs on the paper. If they fail to do so by an appreciable amount, either the printed scale is wrong or the instrument is not of standard construction.

This paper is distributed by the Submarine Signal Company, and the type in present use is known as 15*U*.

### *5234. Motor Speed: Tachometer*

The motor driving the recording mechanism operates from 12 volts direct current and is rated at 1/100 horsepower at a speed of 4,026 r.p.m. This motor speed is normally controlled by means of a governor, but a manual control is also provided, selection being made by means of a switch. The governor is a centrifugal type, attached to one end of the motor frame. A reversing switch automatically changes the direction of the current through the governor contacts and the motor once each revolution of the sprocket roller. This eliminates pitting of the governor contacts and they need attention only about once each season.

Slight adjustments may be made to the governor by means of a knob located on the face of the recorder cabinet. By this the governor may be adjusted to operate at the calibration speed of the instrument. The manual control may be substituted in the event of governor failure. Two knobs control resistors in series with the field of the motor. One knob is for coarse and the other for fine speed adjustment.

For accurate results the motor must always rotate at calibration speed and it is essential to be able to verify this continuously. A Frahm vibrating-reed type of tachometer, located on the face of the cabinet where it is always in view of the operator, provides the means for this verification. The tachometer is composed of seven reeds; the middle reed, vibrating at maximum amplitude, indicates the correct motor speed for the calibration velocity of sound in sea water of 820 fathoms per second. The three reeds to the right and left indicate speeds too high and too low, respectively, by 0.75, 1.5, and 5.0 percent. These percentages are also applicable to the tachometer used in

the 312 Fathometer, although the reeds have different vibration frequencies. The tachometer is enclosed in a case to protect the reeds from injury. It is equally effective as a speed indicator when sounding in either fathoms or feet. If the motor speed changes from any cause, the reeds indicate the direction and degree of change, thus aiding in the readjustment of the governor or in the use of manual control. The various values for the seven reeds in this tachometer are given in table 13.

TABLE 13.—*Tachometer reed values for 808 Fathometer*

| | Left | | | Middle | Right | | |
|---|---|---|---|---|---|---|---|
| Reed No | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Percentage from normal | −5 | −1½ | −¾ | 0 | +¾ | +1½ | +5 |
| Frequency of vibration (in cycles) | 63. 7 | 66. 1 | 66. 6 | 67. 1 | 67. 6 | 68. 1 | 70. 5 |
| Motor revolutions per minute | 3, 825 | 3, 966 | 3, 996 | 4, 026 | 4, 056 | 4, 086 | 4, 227 |
| Equivalent velocity of sound (in fathoms) | 779 | 808 | 814 | 820 | 826 | 832 | 861 |

### *5235. Batteries*

One heavy-duty 12-volt storage battery, or two heavy-duty 6-volt batteries, of 200-ampere-hours capacity or more, should be used to furnish the power for the instrument. This capacity should suffice for 15 hours' continuous operation. The current drain of the battery is 11 amperes. The battery voltage can be checked constantly, while the instrument is in use, by means of the voltmeter on the cabinet. The battery voltage may vary between 9 and 15 volts without interfering with the operation of the instrument.

After each day's operation the battery should be recharged. The charging current should be about 15 amperes and it should be charged for about the same number of hours the instrument was in operation. At the end of the charging period a hydrometer test should be made to see if the battery is sufficiently charged. Since the charging rate and hours of charging required will depend on the age and condition of the battery, it will be necessary to alter them from time to time. Facilities should be arranged so that the batteries can be recharged without removal from the launch. If it is desired to charge the batteries while the instrument is being operated, the battery-charging unit must be arranged so that it does not interfere with the operation of the instrument; for this purpose it may be necessary to use a filter between the charger and the battery. In remote regions a spare set of batteries should be carried in each launch.

### *5236. Installation of Acoustic Units*

The method of securing the fish (see **5231**) to the side of the launch will vary with the dimensions of the vessel, making it impracticable to design one supporting structure for use on launches of various sizes and designs. The following description of an installation used on one of the launches of the Coast and Geodetic Survey is intended to illustrate one of the possible ways of supporting the fish. This method with slight modifications might be used on launches of different design.

With reference to figure 103, the two vertical supports are 1¼-inch extra-heavy brass pipe, threaded at each end. The lower ends screw into the pipe fittings on the fish and the upper ends are screwed into 1¼-inch brass tees. A 1¼- by 3-inch brass

nipple and a 90° brass elbow are screwed into each of the tees, which are connected horizontally by a short length of 1¼-inch brass pipe screwed into the elbows.

The horizontal members that are secured to the deck support most of the weight of the assembly. These members are made of 2- by 3-inch angle iron; they are fastened to two ½- by 3- by 26-inch iron plates which are secured to the deck by lag screws. The outer ends of the angle irons project slightly beyond the side of the launch and secured to them is a ⅜- by 6- by 22-inch iron plate. The vertical pipes supporting the fish pass through two 1⅜-inch holes, 15 inches between centers, in this plate. Each pipe passes through two loose brass collars, one above and one below the iron plate. The support of the fish is secured in place by means of set screws through the brass collars. This arrangement provides for a vertical adjustment of the position of the fish.

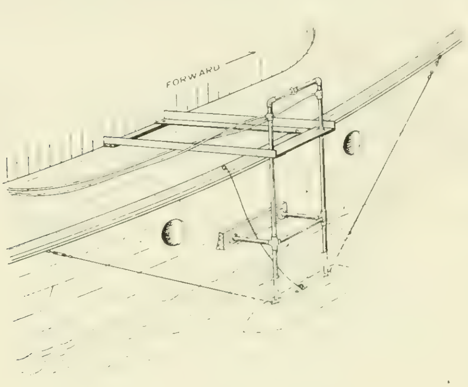

FIGURE 103.—Support for fish of 808 Fathometer.

Just above the waterline is another horizontal support to secure the vertical structure to the side of the launch and prevent lateral movement of the fish. This support consists of two 1¼-inch brass side-outlet tees, three short lengths of 1¼-inch brass pipe, and two brass deck flanges with closed nipples. The tees are drilled so they will slide freely over the vertical pipes. Two setscrews in each tee are used to clamp the pipes in place. The deck flanges are secured to the side of the launch so that their nipples are horizontal. The outer ends of the horizontal pipes screw into the tees, and the inner ends slide over the nipples of the flanges to which they are secured by pins through holes drilled through the pipes and nipples.

Guys leading forward and aft are secured to the vertical pipes by means of clamps located just above the fish. The guys are ¼-inch stranded wire. A safety line attached to a ⅝-inch bronze eyebolt in the top of the fish is fastened to a cleat on deck. The electric cables from the transmitting and receiving units pass through the vertical pipes and pass out of the upper tee openings.

To install the fish, the assembly is lowered over the side and the angle irons are bolted to the deck plates. The lower horizontal pipes are then slipped over the deck flange nipples and pinned. If the draft of the fish is not suitable it may be adjusted by loosening the setscrews in the upper clamps and the lower side-outlet tees, and raising or lowering the fish. The fore-and-aft guys are then fastened on deck and made taut by means of turnbuckles. The safety line is fastened and finally the electric cables are connected to the recorder cabinet.

Where the 808 Fathometer is installed permanently in a vessel, the magnetostrictive elements are removed from the fish and installed in tanks located against the inside skin of the vessel.

### *5237. Operation*

In actual field operations, depths from a half-foot below the fish to 160 fathoms have been recorded. For launch hydrography it is used principally in depths less than 100 fathoms. Where sounding in shoal or moderate depths over comparatively even bottom, a record in greater detail may be obtained by using the fast speed and the scale

in feet. Both the vertical and horizontal representation are at a scale six times that obtained when sounding at slow speed in fathoms. Where the bottom is very irregular, with frequent and rapid changes in depth, the fathom scale should be used in depths greater than 50 feet, thus avoiding the frequent changes of phase which would be necessary on the scale in feet (see **3112**(*d*)). On the fathom scale the changes of depth are not so exaggerated and can usually be followed without difficulty. The possibility of missing a pinnacle rock during a shift in phase is also eliminated.

It is important that the sensitivity control always be kept at the highest value at which the instrument can be operated without introducing strays. The recorded value for a given depth may be changed by as much as 2 feet in some cases by changing the sensitivity control from one extreme to the other. This condition is inherent in all echo-sounding instruments, but in any case the variation in time lag is less at higher values of echo-amplifier gain and by keeping the gain control near the maximum the recorded soundings will more nearly approach the true depths. (See **5163**.)

To save time the fish should be left installed between successive days of hydrography unless it is exposed to damage by so doing. For optimum operation of the instrument, the magnetostrictive elements of the fish must be saturated with water. If the fish, or if the launch and consequently the fish, is removed from the water, these elements dry out and must be soaked in water for a half-hour before use in sounding. On one ship, where the launches were hoisted at night, the elements were kept saturated by placing a watertight canvas sack, filled with water, around the fish so that it was ready for use the instant the launch was lowered into the water.

The fish should be examined periodically to determine whether any dirt or marine growth has accumulated in the magnetostrictive-element housing. This inspection can be made by removing the two diaphragms from the bottom of the fish. In cleaning the elements, care should be taken not to injure the nickel laminations or the rubber-covered wire.

The recorder should be run for a warm-up period of 15 to 30 minutes before sounding or making a bar check (see **557**). It should be operated in the fathom position for this purpose to conserve paper. This warm-up run may be made before the launch is lowered, if it is expected that it will be wanted for sounding, or a bar check, immediately after lowering.

The following spare parts should be kept on hand for each instrument: (1) styluses; (2) spare tubes, two each of types 1851, 1853, and 6*F*6; (3) brushes (for motors and generators); (4) a governor; (5) fathogram paper.

Major repairs should not be attempted while the instrument is in the launch, except in emergencies. Excluding minor matters, repairs should be made only by qualified persons.

*a. Lubrication.*—Every 3 weeks the gear-box cover should be removed and the gear train inspected to see if it is properly lubricated. If any gears appear dry "Singer Motor Lubricant" or a good soft sodium-base cup grease should be applied lightly with a smooth stick.

Once each month the grease plug on each end of the driving motor should be removed and a small amount of the same lubricant used in the gear box should be added.

Every 2 months, or when the dynamotors show signs of binding, the grease plugs should be removed and lubricated with one of the following lubricants: Master Lubricants Company—Lubrico *M*6; or New York and New Jersey Lubricant Company—*F*927; or Standard Oil Company—*G*5990.

*b. Cleaning.*—Before each day's operation, the inside of the recorder cabinet should be wiped clean with a dry rag, and the metal recorder platen rubbed to a polish.

Every 3 weeks the governor and keying contacts should be inspected and cleaned. The contact surface should be filed flat, and if there is evidence of bad pitting, the governor should be renewed.

Every 2 months the driving motor and dynamotor brushes and commutator should be inspected for wear. The commutator should be smoothed with a fine grade of sandpaper (emery must not be used), and the brushes renewed if necessary. After new brushes have been installed, the instrument must be run for 2 hours to wear them in properly.

### *5238. Operating Difficulties*

An 808 Fathometer operating so as to give inaccurate or unsatisfactory results, generally, but not always, gives evidence of this on the fathogram. But it should be noted that a number of unrelated difficulties manifest themselves in the same way. A lack of soundings, inaccurate soundings, or unsatisfactory results may be caused by one of the following:

(*a*) A poor connection or shorting of the cables from the fish, or battery, evidenced by no sounding or continuous marks across the fathogram.

(*b*) Improper pressure of the stylus on the paper, evidenced by no record, torn paper, or a succession of hiatuses of short intervals in the record.

(*c*) Dirt or carbon on the metal platen under the paper, evidenced by horizontal marks throughout the fathogram.

(*d*) Improper echo-amplifier operation, evidenced by the transmitted signal or the echo, or both, being recorded weakly, or not at all; or by a continuous black mark across the fathogram.

(*e*) Improper operation of the contactor mechanism, evidenced by a jagged record of the transmitted signal and echo, a sudden equal change in the recorded position of both, or the entire absence of signals.

(*f*) Defective parts or connections, evidenced by irregular record, lack of record, or continuous marks across the fathogram.

(*g*) Play in the phasing head, evidenced by a sudden change in the recorded position of the transmitted signal and echo. This should be tested by attempting to move the head by hand. Such a fault can be temporarily remedied by inserting three paper shims between the phasing head and its holding ring, placing the shims about an equal distance apart. The head must not be made so tight as to prevent index adjustment.

(*h*) Continued marking of the stylus after depression of the fix-marker button. This is ordinarily not caused by the button sticking, but by oscillation of the amplifier after the button has been released. The remedy is to turn the gain control down momentarily in order to stop the oscillation.

In addition to the difficulties that are evidenced on the fathogram, there are a number of operational troubles which may occur and most of which have occurred on one or more of the instruments in use. Some of these difficulties are still being analyzed and it is expected that the redesign of certain parts may eliminate them.

(*i*) Trouble with the governor or keying contacts—the contacts should be filed occasionally to a uniform surface and the keying contacts or the entire governor renewed if the trouble is not eliminated by filing.

(*j*) Improper operation of the reed tachometer resulting in loss of necessary definition. This may be caused by excessive vibration of the cabinet by external forces. The recorder cabinet should be supported on *Lord* mounts, type 200-*XPH*-60, or some shock-absorbing material, such as rubber.

(*k*) Lack of amplifier gain or unsteady operation may be caused by defective type 1851 or 1853 vacuum tubes. These types of tubes have occasionally functioned erratically; they should be tested for emission and be subjected to a mechanical shock by being rapped sharply during the emission tests.

(*l*) Damage to gears by reason of imperfect design or alinement. The driving motor has been known to become loose on its mounting, which might account for the improper meshing of the gears.

(*m*) Faulty echo-amplifier gain-control operation—caused by salt water running down the gain-control shaft. This may be prevented by sliding a rubber sleeve over the gain-control shaft so the water cannot get to the gain-control resistor inside the cabinet.

(*n*) Lack of high d-c voltage from either of the generators—may be caused by worn brushes or a dirty commutator on either the motor or generator end of the unit.

(*o*) Leaky cable connectors—caused by salt encrustations. The interior part of the connector plugs should be removed and cleaned. Future trouble of this nature can be prevented by wrapping the plugs with rubber tape at the joints. When the fish is stowed on the open deck a cap provided for the purpose should be screwed over the ends of the plugs to prevent salt water entering the openings.

(*p*) Disagreement of soundings recorded on different depth phases, in depths falling within the overlap between these phases. This is because of mechanical imperfections in the phasing mechanism. The amount of this discrepancy should be determined by an accurate bar check (see **557**) in smooth water, or by comparative soundings from a stationary vessel at a place where the bottom is smooth and flat and in calm water. The results of the tests should be adequate for use in correcting the soundings for any such errors. Corrections should be made by reference to phase **A**. Since any such error is due to a mechanical fault, its effect on the recorded depths is six times as great for depths recorded in fathoms as for those recorded in feet; that is, if the error for a certain phase on a certain instrument is ½ foot for a fathogram in feet, the error for the same phase and instrument will be ½ fathom for a fathogram in fathoms.

(*q*) The take-up fathogram roll is driven by a coil-spring belt from the shaft on which the sprocket roller rotates. The tension of this belt is critical. If the coil-spring belt breaks or loses its tension, it must be replaced with a standard replacement part; neither any other type of belt nor a repaired coil-spring belt can be used. The tension must be such that the paper will be tightly rolled on the take-up roller, but so that the belt will slip and *never* cause the fathogram to travel faster than the sprocket roller moves it. (See also **5233** and **5554**.)

## 524. DORSEY FATHOMETER NO. 1

The Dorsey Fathometer No. 1 is a shoal-water, supersonic, visual type of echo-sounding instrument. Its depth range is from a few feet to 150 fathoms, although 40 fathoms is about the maximum to which it is normally used in hydrography. Numerous features have been incorporated in the instrument to make it capable of measuring shoal depths with great accuracy, especially for hydrographic surveying. The most important of these features are:

(*a*) The use of supersonic frequencies, facilitating shoal measurements.

(*b*) A combined transmitting and receiving unit, known as a *transceiver*, to eliminate the separation error.

(*c*) High damping of the transceiver to suppress persistent diaphragm vibration, which is a deterrent to shoal-water soundings.

(*d*) An efficient high-gain echo amplifier, especially designed to be stable and capable of rapid recovery from excessive input voltages.

(*e*) Tuning-fork control of the indicator-motor speed to better than 99.9 percent of the correct value, thus eliminating errors from this source. No adjustment of the motor speed is necessary.

(*f*) Photoelectric tube keying to eliminate moving contacts with their inherent time variations.

(*g*) An expanded depth scale so that readings can be estimated to $\frac{1}{10}$ foot under ideal conditions.

(*h*) Soundings at the rate of 20½ per second are spaced only a few inches apart along the bottom, even at high vessel speeds.

The operation of the Dorsey Fathometer No. 1 is illustrated schematically in figure 104. The operating cycle in producing a sounding can be traced as follows: A beam of light reflected from a rotating mirror strikes a photoelectric tube which, by its photoelectric action in conjunction with associated circuits, activates a vacuum-tube oscillator for a fraction of a millisecond. The amplified electric oscillations energize the magnetostrictive transceiver, which transmits a supersonic sound signal. The echo is received on the same transceiver and amplified by the echo amplifier to a sufficient voltage to

flash the neon tube in the indicator, thereby registering the depth. This cycle is repeated at the rate of 20½ times a second, resulting in as many soundings per second.

The Dorsey Fathometer No. 1 is composed of four separate parts: the transceiver, echo amplifier, indicator, and power supply. The transceiver, echo amplifier, and power supply are nearly identical in circuit arrangements with those of the Dorsey Fathometer No. 3. The functions of these parts are mentioned only briefly here, their construction

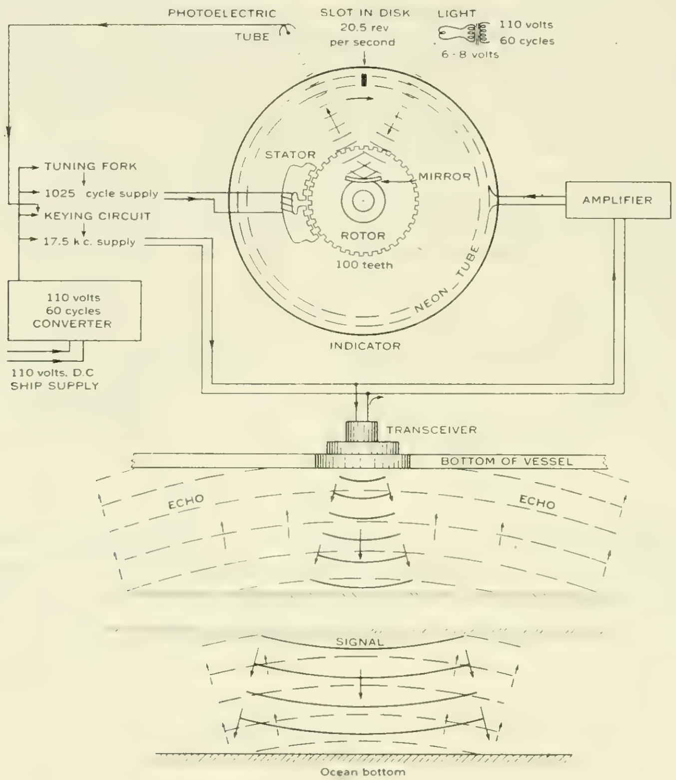


FIGURE 104.—Schematic operating diagram of the Dorsey Fathometer No. 1.

and functions being described in detail in **526** where the Dorsey Fathometer No. 3 is described.

### *5241. Transceiver*

The transceiver, or combined transmitting and receiving unit, operates on the magnetostriction principle. It is a diaphragm type, intended for use in direct contact with sea water, which requires that it be fitted into an opening cut in the bottom of the vessel. It is relatively inefficient in energy conversion but possesses other qualities favorable to shoal-water sounding. Back of the diaphragm are a number of nickel tubes, which form the magnetostrictive element. Their physical dimensions are such that they are broadly resonant at 17.5 kilocycles. A coil is wound around each nickel tube to furnish the necessary magnetomotive force for transmitting, these same coils introducing a voltage in the echo amplifier when the echo impinges on the diaphragm of the transceiver.

The transceiver installed in a hull mounting is shown in figure 105.

Power to operate the transceiver is furnished by a 17.5-kc vacuum-tube oscillator and an accompanying vacuum-tube power amplifier. In addition to the 17.5-kc alternating current, there is a d-c polarizing current of about 1.75 amperes flowing continuously through the transceiver. The purpose of this direct current is to prevent

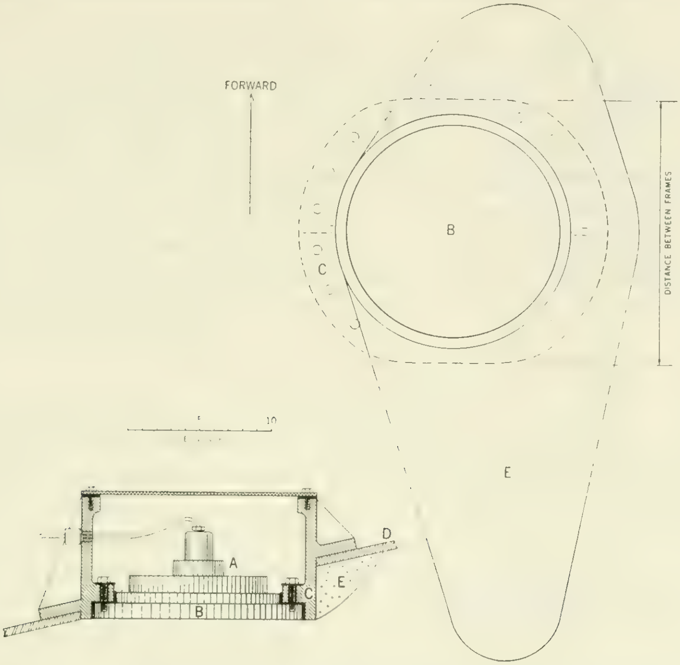


FIGURE 105.—Magnetostrictive transceiver mounting. *A.* Transceiver housing. *B.* Diaphragm. *C.* Hull mounting. *D.* Hull plate. *E.* Fairwater——cement or steel plate.

double periodicity of the transceiver and to furnish the magnetomotive force used in the reception of the echo. (See also **5261**.)

### *5242. Echo Amplifier*

The echo amplifier amplifies the feeble voltage generated across the terminals of the transceiver when an echo is received; it embodies a superheterodyne circuit capable of high gain, and has a high degree of stability and frequency discrimination. The output voltage of this amplifier operates the grid of a type 884 gas-discharge tube, which in turn flashes the indicator neon tube. This amplifier is similar to that used in the Dorsey Fathometer No. 3, except for mechanical details, and except for the fact that no headphone outlet is provided.

### *5243. Indicator*

The visually indicating device of this Fathometer is housed in a black-finished metal cabinet, 10 by 10 by 5 inches in size. The front of the cabinet contains a circular opening, fitted with a glass on which are the circular depth scales, one divided into foot intervals and the other into fathom intervals, up to 20 fathoms. On the lower left-hand rounded edge of the cabinet are two toggle switches. The front switch is for starting and stopping the motor generator that supplies a-c power to the Fath-

ometer, and the rear switch is for starting and stopping the auxiliary starting motor, whose purpose is to bring the synchronous driving motor up to synchronous speed. On the lower right-hand edge of the cabinet is a push button by which the starting motor and the synchronous motor are engaged. The parts included in the cabinet are: the synchronous motor, starting motor, stroboscope starting lamp, circular neon tube, and the index disk.

The synchronous motor is of the reluctance type. The rotor has 100 teeth around its periphery, their slots being parallel to the axis of rotation. An annular channel, cut in the central disk of the rotor, is filled with mercury, its purpose being to discourage *hunting,* or the minute variations in speed of rotation due to acceleration and deceleration caused by electromechanical instability.

The stator consists of three U-shaped pole pieces, spaced 90° apart around the rotor. The teeth of the stator are identical in size to those of the rotor. An energizing coil is wound around each pole piece in such a manner as to permit the maximum flux to pass between the stator and rotor teeth. The relation of the speed of rotation to the frequency of the energizing current is given by $N=\frac{2F}{T}$ (for no polarizing current); in which $N$=the number of revolutions per second, $F$=the frequency of the energizing current in cycles per second, and $T$=the number of teeth in the rotor. In the case of the Dorsey Fathometer No. 1, $F=1025$ cycles per second, and $T=100$ teeth; therefore, $N=20.5$ revolutions per second.

A small universal motor is used to bring the non-selfstarting synchronous reluctance motor to speed. The two motors are engaged by friction coupling. A neon stroboscope aids in synchronizing this motor. The neon lamp of the stroboscope is operated by current from the tuning fork which drives the synchronous motor—this is 1025-cycle current. Light from the neon lamp illuminates the teeth of the rotor so that at synchronous speed these teeth appear to be stationary.

The thin aluminum index disk attached to the synchronous motor is 8½ inches in diameter. An index, shaped like the ace of spades, is cut in this disk, with the pointed end adjacent to the depth scale. The disk rotates between the back of the depth scale and a circular neon tube which is concentric with the depth scale. From a viewpoint in front of the indicator, the entire neon tube is hidden by the disk, except that part exposed by the index slot. When the neon tube flashes at the instant an echo is received, the illumination of this tube appears through the index slot alongside the depth scale at a point corresponding to the depth.

A photoelectric tube, a source of light, and a rotating mirror form part of the keying circuit. The photoelectric tube and a 6- to 8-volt incandescent lamp are located on the top of the indicator cabinet, protected from stray light by metal shields. The light from the lamp passes through a hole in the top of this cabinet and is focused on a rotating concave mirror attached to the synchronous driving motor. This light is then reflected back to the photoelectric tube through a second hole in the top of the cabinet. Once each revolution of the driving motor the light reflected from the mirror falls on the photoelectric tube. At the point in the cycle where the emission of the acoustic signal is desired, usually at a point on the depth scale corresponding to the ship's draft, the mirror must be in a position to reflect the light beam onto the photoelectric tube. The voltage output of the photoelectric tube is then amplified to actuate a type 884 gas-filled discharge tube. One of the characteristics of this latter tube is that it delivers a relatively large amount of current in a very

short interval of time. As previously mentioned, an echo-sounding instrument for use in shoal depths should have a transmitted signal of very short duration. This gas tube is one of the features making this possible. The relay action of this tube allows the 17.5-kc vacuum-tube oscillator to oscillate for a period of approximately 0.0007 second (0.7 millisecond).

By means of a control that changes the time constants of the type 884 keying tube circuit, a signal is transmitted only on alternate revolutions. This is to prevent interference between the transmitted signal and the echo in depths slightly greater than 20 fathoms.

The speed of rotation of the synchronous driving motor depends on the frequency of the electric power supplied to it. For utmost accuracy in sounding, the frequency of the supplied power must remain constant. This is accomplished in the Dorsey Fathometer No. 1 by means of a tuning fork (see **5165*b***). The vibration of the tuning fork is electrically maintained by a vacuum-tube circuit, whose output voltage is amplified sufficiently to drive the motor.

### *5244. Power Supply*

The power supply is housed in a metal frame rack. Included with the power supply are such parts as the 17.5-kc oscillator and amplifier, the tuning-fork circuits, the polarizing rectifier and filter, and the high-voltage and bias rectifiers and filters.

This Fathometer is operated by power derived from the ship's 110-volt d-c supply, which is converted to 110-volt 60-cycle alternating current by means of a 1.5-kva rotary converter. The total power consumed is approximately 1,000 watts.

### *5245. Operation*

The procedure in preparing the Dorsey Fathometer No. 1 for sounding is as follows: The front toggle switch on the left corner of the indicator cabinet is moved to the up position; this action starts the d-c to a-c rotary converter which furnishes the power to all parts. After an elapsed time of less than a minute a 2050-cycle sound will be heard in the indicator. The rear toggle switch on the lower left-hand corner of this cabinet is then thrown to the up position, starting the starting motor. The hinged door on the right side of the cabinet is opened so that the synchronous motor rotor and stroboscope neon lamp may be viewed. The push button on the lower right-hand edge of the cabinet is then pressed to engage the starting motor and the synchronous motor. These two motors are kept engaged until the latter motor has reached synchronous speed, which is 1,230 r.p.m., and which is indicated by the teeth of the rotor, illuminated by the neon tube, appearing stationary. When these teeth first become visible, the push button of the starting motor should be given a series of pushes at the rate of about one per second until synchronization of the motor occurs.

Caution must be observed not to synchronize the motor at half-synchronous speed. At half speed the teeth of the rotor will appear to be stationary under the stroboscopic illumination, but with much less definition. It will also be much more difficult to synchronize the motor at half speed. To guard against this the rotor teeth should be watched from the starting of the motor until it reaches final synchronous speed, noting first when the rotor teeth appear stationary, but keeping the motors engaged until this occurs a second time, when the correct synchronous speed has been reached. Sufficient practice will enable one to start the motor, without the use of the stroboscope, by listen-

ing for the decreasing beats between the sound made by the rotor teeth and the 2050-cycle sound, synchronization of the motor occurring when the beats are no longer heard.

The Fathometer is now ready for sounding. The gain control on the front of the echo amplifier should be adjusted to as high a value as practicable without causing strays and an excessive number of multiple echoes.

### 525. Dorsey Fathometer No. 2

The Dorsey Fathometer No. 2 is a combined sonic and supersonic visual-type of echo-sounding instrument, designed to supplement the Dorsey No. 1, and for measurements in moderately shoal to deep depths. It incorporates some of the accuracy features of the Dorsey Fathometer No. 1 and the depth range of the 312 Fathometer. The Dorsey Fathometer No. 3 has now superseded the Dorsey No. 2 because it combines the features of the Dorsey No. 1 and Dorsey No. 2. For this reason the Dorsey Fathometer No. 2 is described only briefly.

The transceiver, one of the echo amplifiers, and the power supply of the Dorsey No. 2 are very similar to those of the Dorsey No. 1. The echo amplifier of the Dorsey No. 2 is provided with an audio outlet, making it possible to listen to the returning echo with headphones. The principal differences between the two systems are in the indicating mechanisms, and the incorporation of the 312 Fathometer system in the Dorsey Fathometer No. 2. The parts of the 312 Fathometer (see **521**) which are used in conjunction with the Dorsey No. 2 are the oscillator, the 525-cycle motor generator, hydrophones, and the 1050-cycle echo amplifier.

There are two concentric depth scales; the outer graduated from 0 to 100 fathoms, and the inner from 0 to 1,000 fathoms. One neon tube serves for both scales, its light being refracted to the inner scale by means of a prism rotated on a radial arm. An annular disk, carrying the index, rotates between the circular neon tube and the 100-fathom scale at 4.1 revolutions per second, and the radial arm, carrying the prism, rotates inside the disk, just behind the 1,000-fathom scale, at 0.41 revolutions per second. The arm and disk are geared to the same tuning-fork controlled reluctance-type synchronous motor, the speed of which is 4.1 revolutions per second.

The selection between the two scales of the dial is made by throwing a toggle switch on the inside of the indicator cabinet. This selects the photoelectric tube keying circuit associated with one of the two depth scales. A selector switch mounted alongside the cabinet makes the necessary circuit changes from the sonic to the supersonic system or vice versa.

The supersonic system utilizes circuits similar to those in the Dorsey Fathometer No. 1 and is used for the shoaler depths, while the sonic system is operated through circuits similar to those used in the 312 Fathometer and is used for the deeper depths.

### 526. Dorsey Fathometer No. 3

The Dorsey Fathometer No. 3 is a combined sonic and supersonic visual-type sounding instrument, designed for depth measurements from a few feet to several thousand fathoms. This instrument is an outgrowth of the Dorsey No. 1. It embodies all the principles of the Dorsey No. 1, and is essentially the same instrument with the addition of certain equipment, similar to the Dorsey No. 2, to extend the depth range to deeper water. Certain parts, such as the echo amplifier, power supply, and trans-

ceiver, are nearly identical with those in the Dorsey No. 1. The major differences are in the indicating mechanism, and the addition of certain features of the 312 Fathometer.

The several parts of this Fathometer are the transceiver, filter junction box, echo amplifier, indicator, power supply, and certain parts of the 312 Fathometer system (see **521**). The latter are the 525-cycle motor generator, 1050-cycle oscillator, hydro-

FIGURE 106.—Sounding with the Dorsey Fathometer No. 3. The indicator cabinet with its three scales may be seen above the open record book, with the amplifier below it.

phone, echo amplifier, and all the necessary operating controls. A circuit diagram of this instrument is shown in figure 107.

### *5261. Transceiver*

The transceiver (fig. 105) is a magnetostrictive diaphragm-type unit which is fitted into an opening cut in the bottom of the vessel in such a way that the entire diaphragm is in contact with sea water. The steel diaphragm is 14¾ inches in diameter, back of which are 19 short nickel tubes that press against the inner side of the diaphragm. A coil is wound around each nickel tube so that when energized by a 17.5-kc current and a steady polarizing direct current, these tubes contract and expand in unison 17,500 times per second, causing the diaphragm to vibrate at this frequency. Conversely, the vibration of the diaphragm, caused by the variation in pressure of received sound of this frequency, expands and contracts the nickel tubes, inducing an electric current in the coils wound around them, which in turn produces a voltage across the coil terminals. The rectified polarizing current required to operate the transceiver is introduced through a filter which serves the dual purpose of preventing the 17.5-kc current from getting back to the rectifier circuit, and of eliminating strays

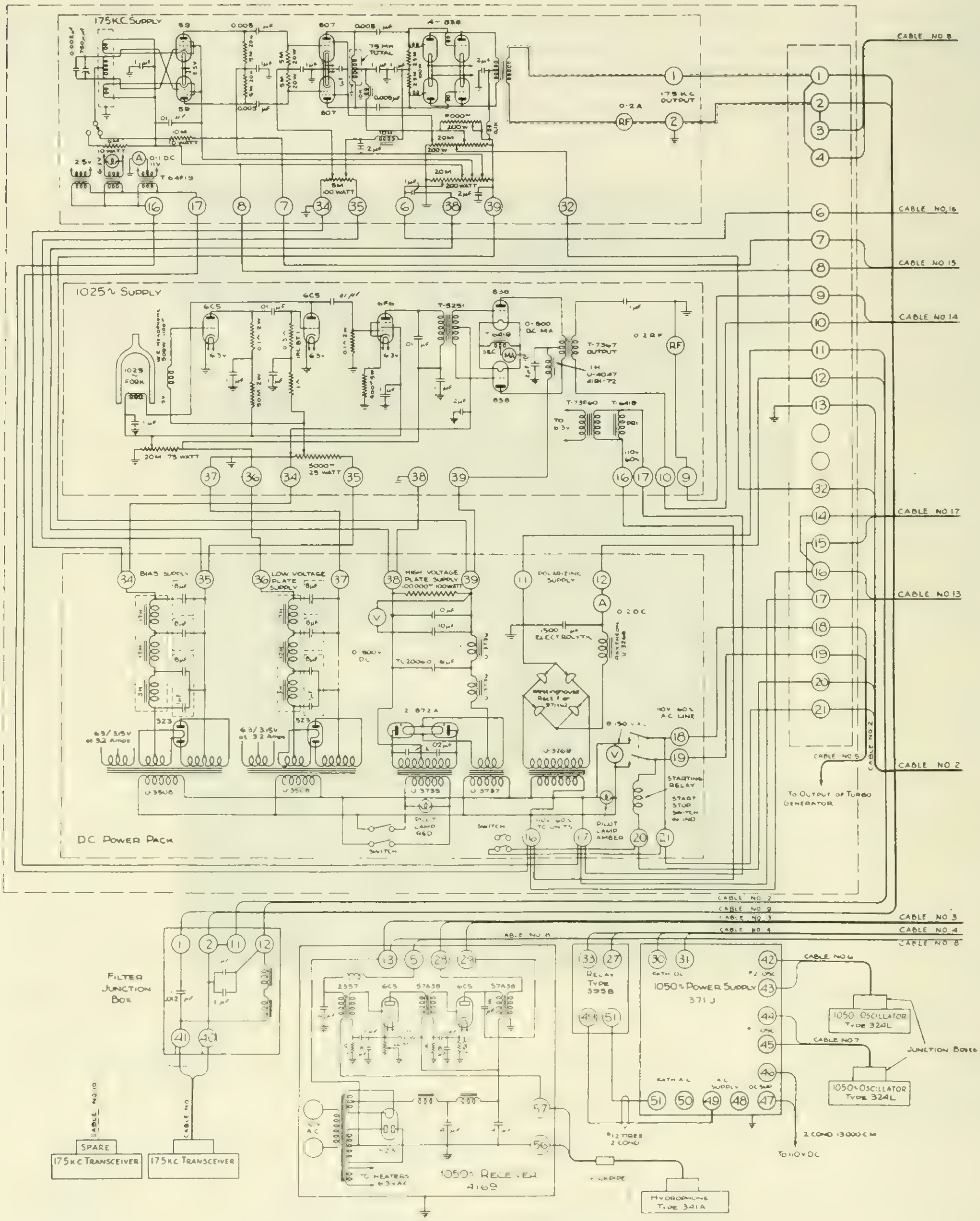

FIGURE 107.—Circuit diagram of Dorsey Fathometer No. 3.

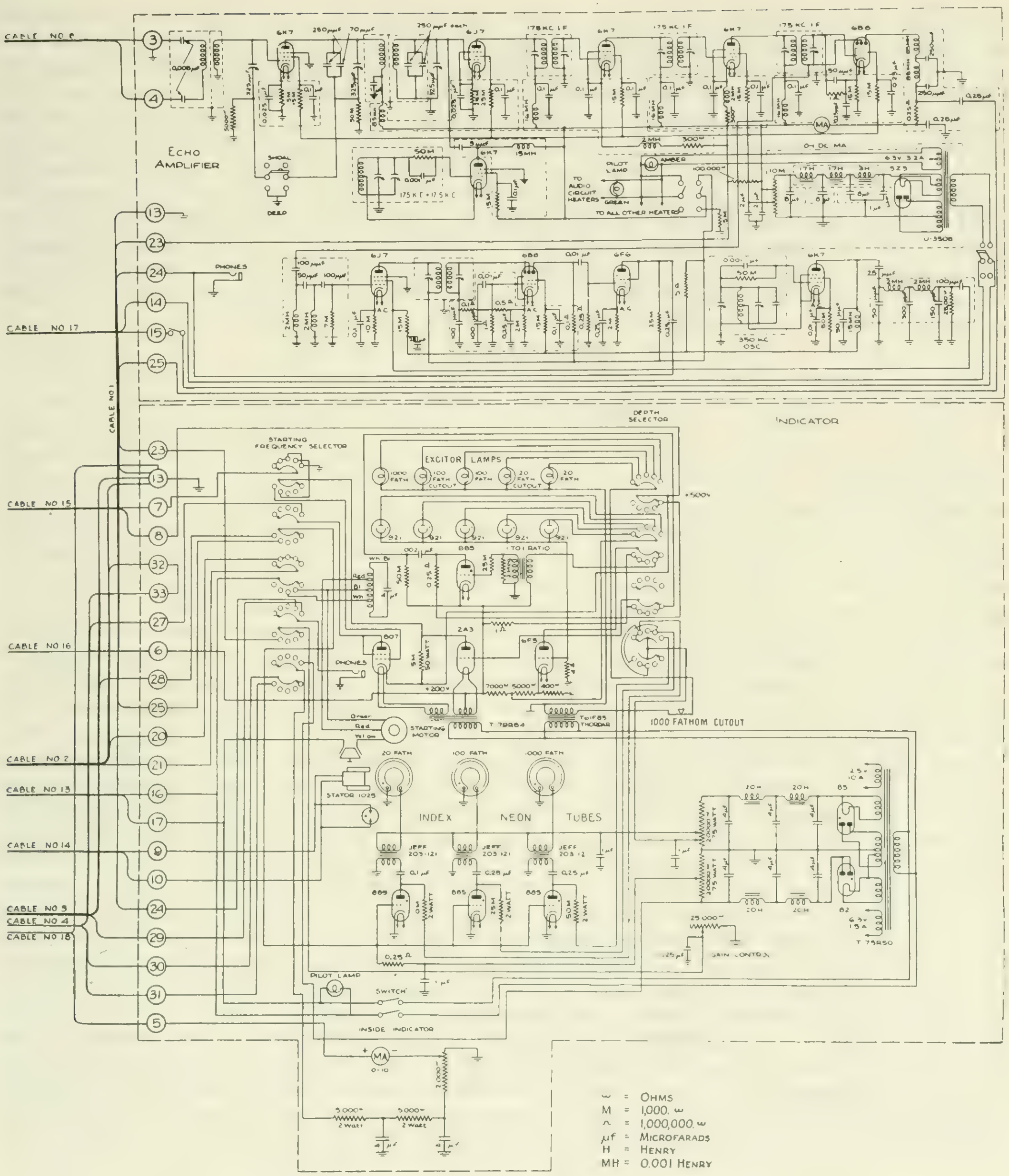


FIGURE 107.—Circuit diagram of Dorsey Fathometer No. 3—Continued

by protecting the transceiver from spurious electric noises arising in the rectifier circuit. This filter is housed in a watertight cast-metal box, size 10½ by 10½ by 8 inches, known as the *filter junction box.*

The transceiver is energized by 17.5-kc power generated by a vacuum-tube oscillator and amplified to about 150 watts. A push-pull electron-coupled oscillator, employing type 59 tubes, generates the oscillations. The 17.5-kc frequency of the oscillator is determined by an inductance-capacitance combination, and can be varied through a range of a few kilocycles by means of a variable condenser. The oscillator is followed by an intermediate amplifier composed of two type 807 tubes arranged in push-pull. This stage is, in turn, coupled to the last power-amplifier stage formed of four type 838 tubes arranged in push-pull parallel. The plate circuits of these tubes are coupled to the transceiver by means of a transformer whose secondary is tuned to 17.5 kilocycles by means of a series 0.012 microfarad condenser located in the filter junction box. Both amplifier stages are biased beyond cutoff and may be considered as class-C amplifiers. The oscillator and power amplifier are located in the top compartment of the power supply.

### *5262. Echo Amplifier*

The echo amplifier is housed in a metal case, size 23¼ by 13½ by 13 inches, so arranged that it is accessible either by lifting a cover or by pulling out the entire subassembly in very much the same way a drawer would be pulled out. The estimated total weight of the echo amplifier is 140 pounds. The echo amplifier employs a superheterodyne circuit, designed so that the 17.5-kc echo voltage is first amplified to some extent and then is increased in frequency to 175 kilocycles, at which frequency it is amplified further. The input transformer which couples the transceiver to the first type 6*K*7 amplifier tube is tuned to 17.5 kilocycles. In the plate circuit of this tube is another transformer tuned to the same frequency, which couples it to the type 6*J*7 detector tube. In the control grid circuit of the type 6*J*7 detector, voltages of two frequencies are mixed—the 17.5-kc echo voltage is mixed with that from a separate oscillator whose nominal frequency is either 157.5 or 192.5 kilocycles. A 17.5-kc echo voltage when added to a 157.5, or subtracted from a 192.5-kc voltage, through the detector action of the type 6*J*7 tube will result in a 175-kc voltage. This 175-kc voltage is amplified by the succeeding two type 6*K*7 tubes, in whose plate and grid circuits are coupling transformers tuned to 175 kilocycles. The last tube of the amplifier is a detector, by whose action, in conjunction with a low-pass filter, the 175-kc voltage is eliminated, leaving the rectified envelope of the echo signal.

By means of a "shoal-deep" switch on the front panel of the amplifier the **Q** (figure of merit) of the input transformer and of the second 17.5-kc transformer may be reduced, which is advantageous in shoal-water sounding. When sounding in deep water it is often desirable to listen for the echo through headphones or a loud speaker. Since the frequency employed in the amplifier is above the audible range, it must be reduced in frequency to be heard. This is accomplished by means of a circuit, composed of an oscillator, detector, and associated circuits, which reduces the second harmonic of 175 kc, which is 350 kc, to an audible frequency. After additional amplification the echo signal can be heard in headphones, or a loud speaker, plugged into a jack on the front of the amplifier panel or into one on the face of the indicator cabinet. This echo-listening circuit can be turned off and on by means of a toggle switch. When it is in operation a green pilot lamp, located on the face of the amplifier, is lighted. The high-voltage rectifier and filter circuit is included in the amplifier cabinet to furnish the necessary plate and filament power for the tubes. Besides those parts located on the front of the amplifier panel that have already been described, there is an off-on switch for the amplifier circuit, an amber pilot lamp to indicate the operation of the amplifier, and a 0- to 1-milliampere d-c meter connected in the plate-circuit output of the type 6*B*8 tube.

### *5263. Indicator*

The visually indicating mechanism is housed in a cast-metal cabinet, size 26 by 15½ by 13 inches, whose total weight is 200 pounds. This cabinet has a hinged front that may be lowered to a horizontal position, and a section of the top is also hinged to furnish access to the interior. The right-hand section of the front is a rectangular hinged frame, about 14½ by 11 inches in size, in which is set a glass plate which contains the depth scales. Directly above the frame is a glass window through which to view the starting stroboscope. On the left side of the front panel are the following numerous controls: a 5-point selector switch for starting and for selection between sonic and supersonic signals; another 5-point selector switch which permits the use of any one of the three depth scales; two gain controls, one for the sonic and the other for the supersonic echo amplifiers; two push buttons, one to operate the starting motor and the other for manual deletion of the trans-

mitted signal (this latter is known as the 1,000-fathom cutout); a milliammeter to show the current to the carbon-button hydrophone; a jack into which headphones may be plugged when listening for the echo; and a pilot lamp to show whether the Fathometer is in operation.

There are three circular depth scales whose ranges are 0 to 20, 0 to 100, and 0 to 1,000 fathoms. The 20-fathom scale is 8 inches in diameter, and contains two scales, one divided into foot intervals with every fifth division numbered, and the other into fathom intervals with every division numbered; the 100-fathom scale is 3¾ inches in diameter, divided into fathom intervals, every tenth division being numbered from 10 to 100; and the 1,000-fathom scale is 3¾ inches in diameter, and divided into 10-fathom intervals, every tenth division being numbered from 100 to 1,000. In a separate compartment in the indicator directly behind the depth scales are three index disks and three neon tubes associated with the depth scales. The functions of the index disks and neon tubes are described in **5243**.

The principal parts and circuits in the indicator cabinet are the driving motor, starting motor, starting stroboscope, keying photoelectric tubes and exciter lamps, keying circuits operated by the photoelectric tubes, gas-discharge tubes and circuits for flashing the neon tubes, and a plate-voltage and bias-voltage rectifier and filter circuit to furnish power to the various vacuum-tube circuits in the cabinet.

The synchronous driving motor is of the reluctance type, run by 1025-cycle current furnished from a tuning-fork circuit. Its rotor has 100 teeth cut in the periphery, parallel to the axis of rotation; and the stator, concentric with the rotor, has teeth that match in size those of the rotor; coils are arranged on the stator so as to cause the flux to pass between the stator and rotor teeth. At synchronism the motor speed is 20.5 r.p.s. On the same shaft with the driving motor is a small 60-cycle starting motor used to bring the former to synchronous speed. A stroboscope, described in **5243**, aids in synchronizing this motor.

The 20-fathom index disk is direct-connected to the driving motor and rotates at 20.5 r.p.s., while the 100- and 1,000-fathom index disks rotate at 4.1 and 0.41 r.p.s. respectively. The two latter are coupled to the synchronous driving motor through reduction gears.

The keying circuit contains five photoelectric tubes, any one of which may arbitrarily be switched into operation, depending on the depth. Each of the three depth scales has a photoelectric-tube circuit that performs the necessary keying functions associated with that scale.

The 20-fathom scale has two photoelectric tubes. One of these is actuated 20.5 times per second by the reflected light from a mirror rotating at that speed, or once each revolution of the index dial. The other photoelectric tube is actuated by a second mirror rotating at one-half the speed of the former, thereby transmitting a signal only every alternate revolution, to prevent interference with the receipt of the echo from depths near 20 fathoms.

The 100-fathom scale also has two photoelectric tubes whose performance is similar to those associated with the 20-fathom scale, except that they are actuated by light shining through openings in rotating disks which take the place of the rotating mirrors.

The 1,000-fathom scale has one photoelectric tube actuated by light shining through an opening in a rotating disk. When this scale is used the emission of the signal can be prevented manually by a push button on the front of the indicator, thus eliminating interference between the transmitted signal and echoes arriving near the 1,000-fathom mark on the dial.

The appropriate depth scale of the instrument is chosen by means of the depth-selector switch on the front panel. This switch connects the proper photoelectric tube and its associated 6- to 8-volt exciter lamp so they perform the necessary keying functions related to the depth scale selected. There is an index adjustment provided for each photoelectric tube and its exciter lamp, by which the position where keying starts may be changed relative to the depth scale. The locations of these five adjustments in the indicator are shown in figure 111. (See also **5542**.)

At the same time that the depth-selector switch connects the proper photoelectric tubes, it also connects the circuits that flash the neon tubes behind the proper index disks. There are three such circuits, one for each depth scale, each incorporating a type 885 gas-discharge tube.

For the first two positions of this depth-selector switch the 20-fathom dial neon tube operates. For the next two positions of this switch both the 20- and 100-fathom dial neon tubes operate, and for the fifth position both the 100- and the 1,000-fathom dial neon tubes operate. The advantage of two neon tubes operating simultaneously is that the shoaler scale may then be read as a vernier with reference to the deeper scale.

The three neon tubes behind the three index disks are caused to flash in the following manner: A type 885 tube discharges a condenser in series with the low-impedance winding of a step-up trans-

former. The increased voltage occurring across the secondary of the transformer flashes the neon tube. A polarizing voltage of about 350 volts direct current helps to decrease the discharge voltage required of the type 885 tube.

### *5264. Keying Circuit*

A direct-coupled amplifier using type 6*F*5 and 2*A*3 tubes, which is actuated by the photoelectric tubes, forms the nucleus of the keying circuit. A 5,000-ohm resistor in the plate circuit of the type 2*A*3 tube acts as a grid resistor between the grid and cathode of the 17.5-kc oscillator. When the 2*A*3 keying tube is drawing current, as it normally does between keying periods, the voltage drop across the 5,000-ohm resistor biases the oscillator sufficiently to prevent oscillations. When the grid of the 2*A*3 tube is made sufficiently negative by the amplified photoelectric keying impulse the voltage drop across the resistor is reduced to a sufficiently low value to permit the oscillator to operate. The type 6*F*5 tube that precedes and is directly coupled to the type 2*A*3 tube, amplifies the output of the photoelectric tube. Two additional circuits are associated with the direct-coupled amplifier: One is a type 885 gas-discharge tube that can be switched into the circuit, between the type 6*F*5 and type 2*A*3 tubes, to shorten the transmitted signal for shoal soundings when the 20-fathom scale is used. The other is a type 807 tube that is connected to the direct-coupled amplifier in such a way that its grid operates from the type 2*A*3 tube output, and the plate circuit of the type 807 tube operates the keying relay for sounding with sonic signals, using the 312 Fathometer acoustic system.

When the instrument is first put into service it is usually necessary to adjust the length of the transmitted acoustic signal used in the 100-fathom circuit. This adjustment is made as follows: With the synchronous driving motor stopped, set the depth-selector switch on position 3 and the frequency-starting switch on position 4. Turn the motor slowly by hand in the normal direction of rotation and note the position, on the 20-fathom dial, of the first and last flashes which mark the beginning and end of the acoustic signal. The separation between the first and last flash should be about 5 fathoms. The keying is governed by an arrangement comprising two shutters carried by the shutter disk. During normal operation the position of the following edge of the leading shutter determines the beginning of the transmitted signal, and the leading edge of the following shutter determines the end of the signal. Hence, by adjusting the following shutter, the length of the signal may be adjusted without changing the time at which the signal is transmitted. Each shutter is slotted and held in position behind the disk by means of a screw through the slot.

Exactly the same procedure is followed for the 100-fathom cutout circuit with depth-selector switch setting 4 and the starting-frequency switch still on position 4.

And the same procedure is followed for the sonic circuit using depth-selector switch setting 5 and starting-frequency switch setting 5 except that, in this case, the length of the keying period should be equivalent to a 50-fathom movement of the index with respect to the 1,000-fathom depth scale.

The shutter to be adjusted, in each case, can be easily identified, since it will be illuminated by the associated exciter lamp.

### *5265. Power Supply*

The power supply is housed in a metal rack, 51 inches high, 21⅝ inches wide, and 21½ inches deep, whose weight is 475 pounds. The circuits of the power supply are contained in three compartments arranged like drawers, to which access may be had by pulling out the subassemblies. In the upper compartment is the 17.5-kc oscillator and amplifier whose purpose is to furnish power to the transceiver (see **5261**). The middle compartment contains the tuning fork and associated circuits, which furnish 1025-cycle power to the synchronous motor. The lower compartment contains the high-voltage, intermediate-voltage, and bias-voltage rectifiers and filters, and the transceiver polarizing circuits.

The front of each compartment is a panel. On the top panel are two meters; a 0- to 2-ampere a-c meter for measuring the 17.5-kc current to the transceiver, and a 0- to 1-ampere d-c meter for measuring the plate current of the last 17.5-kc amplifier tubes. Between these two meters is a dial for changing the frequency of the oscillator. On the left of the panel is a push button by which the 17.5-kc oscillator may be turned on for testing.

On the middle panel are two meters; a 0- to 2-ampere a-c meter to indicate the 1025-cycle current to the synchronous motor, and a 0- to 0.5-ampere d-c meter to indicate the plate current to the 1025-cycle power-amplifier tubes.

On the lower panel are three meters; a 0- to 1,500-volt d-c meter to indicate the voltage of the high-voltage rectifier circuit, a 0- to 150-volt a-c meter to indicate the supply-line voltage, and a 0- to 2-ampere d-c meter to indicate the polarizing current flowing through the transceiver. In addition to these meters there are two toggle switches on this panel, one to operate the 110-volt line relay, and the other to turn on the high-voltage rectifier.

The tuning fork and its circuits furnish 1025-cycle power to the synchronous driving motor. The tuning fork, made of low temperature coefficient steel, is of conventional design. It is driven by a two-tube amplifier. Adjacent to the fork tines are two coils: one is a headphone receiver, known as the pick-up coil, which is magnetically coupled to the outside of one tine; the other is an iron-core coil, known as the driving coil, which is located between the fork tines. The input of the vacuum-tube amplifier is connected to the pick-up coil, and the output is connected to the driving coil. The tuning fork forms a coupling between the input and output of the amplifier, permitting oscillations

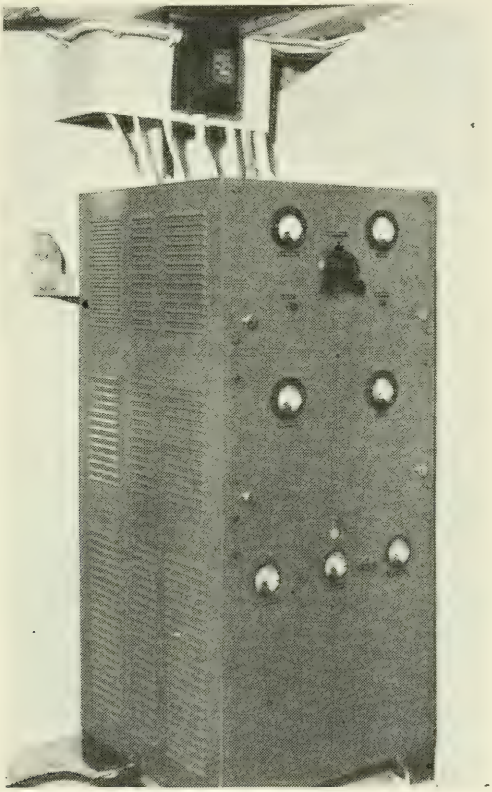

FIGURE 108.—Power supply rack of Dorsey Fathometer No. 3.

at a frequency determined by the tuning fork. Part of the voltage of this circuit is used to operate a type 6*F*6 tube amplifier, whose power output is further amplified by two type 838 power tubes arranged in a push-pull circuit.

On some ships of the Coast and Geodetic Survey the primary source of power to operate the Dorsey Fathometer No. 3 is a 110-volt, 5-kva turbogenerator, but on other ships a d-c to a-c rotary converter is used for this purpose.

There have been cases where the 5-kva turbogenerator governor has failed to function. Such failure may result in high voltage sufficient to damage parts of the Fathometer. On one ship, governor failure was frequent enough to warrant the installation of an overvoltage circuit breaker. In any case, the capacity of the fuses placed in the supply line should not exceed 30 amperes for a normal Dorsey Fathometer No. 3 installation.

### *5266. Operation*

The Dorsey Fathometer No. 3 is put into operation by the following procedure: After starting the primary source of power, which may be either a steam turbogenerator or a rotary converter, the starting-frequency switch on the front of the indicator cabinet is turned to position 2. Less than a minute is required for the vacuum tubes to become sufficiently warm to operate, after which a 2050-cycle sound will be heard in the indicator. Now the push button marked "motor starting," located directly above the starting-frequency switch on the cabinet, is pressed to start the starting motor, which drives the synchronous motor. Just before synchronous speed is reached the starting switch is turned to position 3, which reduces the torque of the starting motor, thus permitting synchronization to be accomplished more easily.

A stroboscopic system has been incorporated in the indicating mechanism to aid in synchronization. This consists of a neon tube, excited from the 1025-cycle source, the intermittent light from which falls on the periphery of the synchronous-motor flywheel, which contains 100 teeth. At synchronous speed the stroboscopic effect makes these teeth appear stationary. The teeth may be viewed through a small window which is just above the 20-fathom dial. Sufficient experience, however, will enable one to start the synchronous motor by ear, without resorting to the stroboscopic method. The synchronous motor will operate in some cases at a submultiple of synchronous speed, and this possibility must be avoided by following the instructions in **5245**. The speed should be finally verified by counting the number of revolutions of the 1,000-fathom index disk, which should revolve a trifle more than four times in 10 seconds (0.41 r. p. s. to be exact). This check need be only approximate since an incorrect speed will always be an even submultiple of correct speed.

After the motor has been synchronized, the starting-frequency switch is turned to position 4, if supersonic soundings in depths less than 300 fathoms are desired. In this case the depth-selector switch is set on position 1, 2, 3, or 4, depending on the depth to be sounded. If the depth exceeds the limit of the supersonic sounding range of the instrument, the starting-frequency switch is placed on position 5 and the depth-selector switch also on position 5, assuming that the instrument has been adjusted by setting the indexes in accordance with **5542**.

Table 15 will serve as a guide in setting the depth-selector and the starting-and-frequency switches. **Any combination of the two switches other than those tabulated must be scrupulously avoided when the instrument is used for hydrographic surveying,** because an error will be introduced due to the relatively large time lag of the electromagnetic keying relay used in the sonic system. To illustrate the use of table 15, if the depth of water, in fathoms, is between 3 and 20, 25 and 40, 45 and 60, etc., position 1 and 4, respectively, of the depth-selector and starting-frequency switches may be used to the limit of the sounding range of the supersonic system, assuming that the bottom is regular enough to warrant the use of the 20-fathom dial. The intervening ranges, in fathoms, of 20 to 25, 40 to 45, 60 to 65, etc., correspond to periods of paralysis of the echo amplifier caused by the transmission of the signal. The paralysis range is not necessarily exactly 5 fathoms but should be considered as such to avoid any possibility of error due to the paralysis. The alternate paralysis ranges, in fathoms, of 20 to 25, 60 to 65, 100 to 105, etc., can be accommodated on positions 2 and 4 of the two switches as indicated in the second line of table 15. The remaining paralysis ranges, in fathoms, of 40 to 45, 80 to 85, etc., require positions 3 and 4 of the two switches.

This latter switch arrangement, depth-selector switch on position 3 and starting-frequency switch on position 4, will accommodate the ranges, in fathoms, of 40 to 100, 110 to 200, 210 to 300, etc., to the limit of the sounding range of the supersonic system. The paralysis ranges, in fathoms, of 100 to 110, 300 to 310, etc., are accommodated by placing the two switches on positions 4 and 4, but the range of 200 to 210 fathoms requires the use of the 1,000-fathom cutout switch. Best results will be obtained in this range by placing the two switches on positions 3 and 4, and manually deleting two consecutive signals of every four index revolutions by means of this 1,000-fathom cutout. Such a cycle is represented by the next to last column in table 15. From the above discussion the rest of the table will be apparent.

The ranges in this table represent actual depths of water and consequently values that will be registered on the dials, for an average draft of the transceiver has already been taken into consideration in all numbers in the first 10 columns. When the shoal-normal switch is placed on the shoal position the instrument will dependably measure depths of 2 fathoms.

Table 16 is given to illustrate the functioning of the Dorsey Fathometer No. 3. For example, the fourth and fifth lines in this table convey the information that if supersonic operation with registration on the 20-fathom dial is desired, the depth-selector and starting-frequency switches should be placed on positions 1 and 4 or on 2 and 4, the choice being made according to table 15. Furthermore, from table 16 the elements and parts connected and used in the various circuits may be determined for different switch settings, and the number of signals transmitted per second is given. The reference numbers appearing in this table under the heading "Circuits used" refer to the corresponding elements or parts listed and described in table 14. These reference numbers in tables 16 and 17 do *not* refer to terminal posts and should not be confused with the numbers used to designate them.

TABLE 14. *Parts and circuits of Dorsey Fathometer No. 3 referred to in tables 16 and 17*

[The numbers 1 to 67 are assigned for reference purposes only and have no other significance. They do not refer to terminal posts.

INDICATOR

I. *Keying.*

*A.* Photoelectric tubes.

1. soundings once every revolution of the 20-fathom index disk.
2. soundings every alternate revolution of the 20-fathom index disk.
3. soundings once every revolution of the 100-fathom index disk.
4. soundings every alternate revolution of the 100-fathom index disk.
5. soundings once every revolution of the 1,000-fathom index disk.

*B.* Exciter lamps.

6. associated with 1.
7. associated with 2.
8. associated with 3.
9. associated with 4.
10. associated with 5.

*C.* Thermionic tubes in keying amplifier.

11. type 6*F*5 (vacuum triode).
12. type 885 (gaseous triode).
13. type 2*A*3 (vacuum triode).
14. type 807 (vacuum pentode).

II. *Indicating.*

*A.* Index neon tubes.

15. located behind 20-fathom index disk.
16. located behind 100-fathom index disk.
17. located behind 1,000-fathom index disk.

*B.* Type 885 tube circuits to flash index neon tubes.

18. associated with 15.
19. associated with 16.
20. associated with 17.

III. *Rectifier circuits.*

*A.* Positive, furnishing

21. polarizing voltage for 15, 16, and 17.
22. plate voltage for 18, 19, and 20.

*B.* Negative, furnishing

23. bias voltage to 18, 19, and 20.
24. hydrophone current.

IV. *Functional switches.*

[In describing these switches, the wafers are considered in order from top to bottom when the front of the indicator cabinet is fully opened. And for each wafer, the common arm which connects to the switch points on the left-hand side of the wafer (L) is listed first. This common arm is just to the right of the supporting columns.]

*A.* Depth-selector switch—connecting

25. (L) 500 volts d-c to 12.
26. (R) 6.3 volts a-c to 6, 7, 8, 9, or 10.
27. (L) plate of 11 to grid transformer of 12 or 1 megohm load resistor.
28. (R) 87 volts d-c to 1, 2, 3, 4, or 5.
29. (L) grid of 13 to plate of 12 or 1 megohm load resistor.
30. (R) (*blank*).
31. (L)
32. (R) } plate voltage (22) to combinations of 18, 19, and 20.

IV. *Functional switches*—Continued.

*B.* Starting and frequency-selector switch—connecting

33. (L) plate of 13 to 34 or grid of 14.
34. (R) grid circuit of 17.5-kc oscillator (55) to ground or to 33.
35. (L) common grid circuit of 18, 19, and 20 to sonic (53) or supersonic (51) amplifier.
36. (R) plate of 14 to sonic keying relay (60). **(Caution 1,000 volts!)**
37. (L) 110 volts, 60 cycles to indicator starting motor.
38. (R) 110 volts, 60 cycles to Fathometer supply line relay.
39. (L) gain-control rheostat to supersonic amplifier.
40. (R) phone jack to supersonic-amplifier audio channel (52), or to sonic-amplifier audio output (54).
41. (L) 110 volts d-c to starting relay for 525-cycle motor generator (58).
42. (R) polarizing current source (24) to hydrophone.

V. *Motors.*

*A.* For starting.

43. 110-volt 60-cycle motor.
44. push-button switch.
45. autotransformer.
46. 4-microfarad condenser.

*B.* For synchronizing.

47. 1025-cycle non-selfstarting synchronous motor.
48. 1025-cycle tuning fork (in power-supply rack).
49. thermionic-tube tuning-fork circuit (in power-supply rack).
50. 1025-cycle power-amplifier circuit (in power-supply rack).

### Echo Amplifier

I. *Supersonic.*

51. 17.5-kc amplifier.
52. audio-channel phone output.

II. *Sonic.*

53. 1050-cycle amplifier.
54. audio phone outlet.

### Power Supply

I. *Supersonic.*

55. 17.5-kc vacuum-tube oscillator (type 59 tube).
56. 17.5-kc power amplifiers (types 807 and 838 tubes).
57. high-voltage d-c rectifier circuit and time-delay relay.

II. *Sonic.*

58. 525-cycle motor generator.
59. speed (frequency) control adjustment for 58 and frequency meter.
60. keying relay.

### Acoustic Units

I. *Supersonic.*

61. transceiver.
62. circuit furnishing polarizing current to 61.

II. *Sonic.*

63. type 324 electromagnetic oscillators.
64. hydrophones.

### Power Source

65. turbogenerator or rotary converter.
66. ship's 110-volt direct current.
67. 110-volt 60-cycle for 53 (if d-c is not used).

### *5267. Diagnosis of Faulty Operation or Failure*

Table 17 is furnished for use in diagnosing the cause of faulty operation or failure of the Dorsey Fathometer No. 3. Each line in this table represents one case of faulty operation. Each case is described by the position of the **X**-marks in the first 10 columns of this table and the switch positions under the heading "Setting of functional switches." The **X**-marks are to be considered as referring to a faulty condition, normal operation being inferred by blank spaces in any of the 10 columns. The reference numbers, entered in the column headed "Parts involved," refer to the items in table 14 that may be wholly or partly responsible for the trouble. These numbers must not be confused with terminal-post numbers. The letters in the last column of table 17 refer to the explanatory paragraphs identified with corresponding letters that follow table 18. It is assumed that the power switch inside the indicator cabinet is turned on, and the shoal-deep switch is on the deep position.

To aid in interpreting this table, assume the following case of faulty operation: With the starting-frequency switch on position 4, no matter whether the depth-selector switch is on position 1, 2, 3, or 4, there is no registration on the 20-fathom dial of transmitted signals, of echoes either at normal or high gain of the echo amplifier, or of strays at high gain of the echo amplifier; but all are registered normally on the 100-fathom dial—that is, on the two positions of the depth-selector switch which connect the 100-fathom index neon-tube circuit as given in table 16. A case of faulty operation thus characterized is dealt with in the fourth line of table 17.

TABLE 18.—*Circuit voltages of Dorsey Fathometer No. 3*

[This table assumes 60-cycle line supply of 110 volts which is the value at which the instrument should normally be operated.]

| | Terminal post number | Voltage or current |
|---|---|---|
| INDICATOR | | |
| *D-C Supply:* | | |
| Index neon tubes (polarizing) | | 350–375 volts. |
| Plate circuit of type 885 tubes | | 270 volts. |
| Grid circuit of type 885 tubes | | −45 volts. |
| *Keying Circuit:* | | |
| Anodes of photoelectric tubes | | 83 volts. |
| Cathode of type 2*A*3 tubes and plate of type 6*F*5 tubes | 6 | 200 volts. |
| Plate of type 2*A*3 tubes (and grid circuit of type 59 oscillator). | 7 | 265–275 volts. |
| Plate load resistor of type 2*A*3 tubes (and cathode circuit of type 59 oscillator). | 8 | 500 volts. |
| Drop across load resistor of type 2*A*3 tubes (which is the bias for type 59 oscillator). | | 225–235 volts. |
| Keying relay in plate circuit of type 807 tubes | 32–33 | 1,100–1,300 volts. |
| POWER SUPPLY | | |
| 17.5–*Kc Oscillator Circuit:* | | |
| Grid circuit of type 59 oscillator (and plate of type 2*A*3 tubes). | 7 | 265–275 volts. |
| Cathode circuit of type 59 oscillator (and plate load resistor of type 2*A*3 tubes). | 8 | 500 volts. |
| Screens of type 59 oscillator | | 700 volts. |
| Plate circuit of type 59 oscillator | | 1,000 volts. |
| 17.5–*Kc Power Amplifier*: | | |
| Grid circuit of type 807 tubes | | −50 volts. |
| Screens of type 807 tubes | | 200–250 volts. |
| Plate circuit of type 807 tubes | | 1,000–1,200 volts. |
| Grid circuit of type 838 tubes | | −230 volts. |
| Plate current of type 838 tubes (key down) | | 160 ma. |
| 17.5–kc current to transceiver (key down) | | 0.58–0.60 ampere. |
| 1025–*Cycle Power Supply*: | | |
| Grid circuit of type 6*C*5 tubes | | (Approx) −2.3 volts. |
| Plate circuit of type 6*C*5 tubes (and screen of type 6*F*6 tubes). | | 225–250 volts. |
| Plate circuit of type 6*F*6 tube | 36 | 315 volts. |
| Plate current of type 838 tubes | | 180–200 ma. |
| 1025-cycle current to synchronous motor | | 0.8–1.0 ampere. |

TABLE 18.—*Circuit voltages of Dorsey Fathometer No. 3*—Continued

[This table assumes 60-cycle line supply of 110 volts which is the value at which the instrument should normally be operated.]

| | Terminal post number | Voltage or current |
|---|---|---|
| POWER SUPPLY—Continued | | |
| *D-C Supply:* | | |
| Polarizing current to transceiver | 11–12 | 1.7–1.8 amperes. |
| High voltage | 39 | 1,350 volts. |
| AMPLIFIER | | |
| 17.5-*Kc Echo Amplifier:* | | |
| Plate circuits | -------- | 250 volts. |
| Screen circuits | -------- | 110 volts. |
| Plate current of type 6*B*8 (measured by meter in face of cabinet). | -------- | 0.8–0.85 ma. |

In the following paragraphs lettered (*a*) to (*r*), the reference numbers refer to elements and parts as numbered in table 14:

(*a*) *Photoelectric tube testing and adjusting.*—Measure the voltage at the anode of the specified photoelectric tube (1, 2, 3, 4, or 5) with a high-resistance d-c voltmeter and compare with the value given in table 18. Type 921 photoelectric tubes are gas-filled and will not function properly in this instrument at 90 or more volts. Measure the continuity from the grid of the type 6*F*5 keying tube (11) to the cathode of the specified photoelectric tube.

Ensure that the socket makes good electric contact at both ends of the specified photoelectric tube by cleaning the contact areas of both ends of the tube and the socket.

Determine if the specified photoelectric tube is held tightly in its socket and, if not, remove the tube and bend the socket ends slightly in such a manner as to hold the tube firmly. The slotted light-shield must first be removed before removing either photoelectric tube 1 or 2 in order to avoid excessive bending of the socket ends when removing or replacing the tube. These tubes are supported at the ends of the two arms and are energized by light reflected from the concave mirrors.

In case photoelectric tube 1 or 2 is specified, determine if the spot of reflected light passes near the center of the slot in the light-shield and, if not, adjust the corresponding mirror by gently bending the mirror frame a slight amount, using care not to break the mirror. In case photoelectric tube 3, 4, or 5, each of which receives light directly from its associated exciting lamp, is specified, be sure that the photoelectric tube is nearly centered with respect to the beam of light and hence is completely illuminated by the uninterrupted beam (see 5542).

Replace the specified photoelectric tube, if necessary.

(*b*) *Exciter lamps.*—If exciter lamp 6 or 7, supported on the ends of the arms adjacent to photoelectric tubes 1 and 2 respectively, is to be replaced, regular Mazda type 1130, spherical clear bulb, 6–8 volts, 21 cp, double-contact, bayonet-base lamps should be used. When any of the other three exciter lamps (8, 9, and 10) is to be replaced, a special lamp must be used which has a tubular ⅝-inch clear bulb (*T*–5), but with base and filament similar to the above type. The latter special lamps with *T*–5 bulb may be obtained from the Washington Office, and several should be kept on hand.

After any lamp is replaced it is usually necessary to readjust the corresponding index (see 5542).

(*c*) *Keying circuit adjustment—supersonic system.*—Test the specified tubes (11, 12, 13, or 14). Measure all related voltages and compare with corresponding values in table 18. Test all circuit elements.

When the supersonic system is being used, if there is evidence that the keying circuit is not operating properly and is in need of adjustment, proceed as follows: Set the depth-selector switch on position 1 and the starting-frequency switch on position 4. In the top compartment of the power supply is a potential divider with four adjustable taps. Measure the voltage to ground of the two taps nearest to ground potential on this divider. If the voltages measured at these taps are not 200 and 500 they should be adjusted to be so. If the circuit then fails to key the vacuum-tube oscillator (55) properly on the first four positions of the depth-selector switch, the 500-volt tap should be moved slightly closer to ground. On the other hand if the oscillator (55) appears to key too readily as evidenced by continuous oscillations through a whole cycle, or a portion of a cycle greater than the normal signal, when the depth selector is on position 3 or 4, for example, then the 500-volt tap should be moved to a slightly higher value. The third and fourth taps above ground should then be adjusted to 200 and 500 volts above the final value of the second tap, as measured with the depth-selector switch on position 1.

(*d*) *Keying circuit adjustment—sonic system.*—If the keying circuit does not operate properly when the sonic system is being used, the keying circuit voltages should be adjusted as described in (c). If the sonic keying relay (60) still fails to function properly, the voltage at the plate of the type 807 tube (14) in the indicator should be measured and adjusted to some value between 1,100 and 1,300 volts. If the relay (60) fails to function when the voltage is 1,300 volts, the relay contacts must be inspected and cleaned if necessary. In any case, the contacts should be adjusted to as small a separation as possible without risk of failure to interrupt the current flowing into the type 324 oscillators (63). And furthermore, the voltage supplied to the plate of the type 807 keying tube (14) should be kept as low as possible.

(*e*) *Index neon tubes.*—Examine the physical condition of the specified index neon tube (15, 16, or 17). Check the ground connection on one end of the specified neon tube. Measure the polarizing voltage (21) supplied to the other end of the specified index neon tube.

(*f*) *Index gas discharge tubes.*—Test the specified type 885 tube (18, 19, or 20). Measure the values of voltage (22 and 23) supplied to the specified type 885 tube and compare with the corresponding values in table 18. Test the circuit elements associated with the specified type 885 tube, including the insulation and continuity of the transformer in the plate circuit.

(*g*) *Indicator power supply*.—Test the rectifier tubes (type 83 for positive, and type 82 for negative voltage). Test the various circuit elements. In case of failure of hydrophone current (24), test the elements of the resistance-capacitance filter in the indicator, the inductance-capacitance filter in the sonic amplifier (53) and the milliammeter in the indicator.

(*h*) *Selector switches*.—Examine the physical condition of the specified half-sections of the wafers of the starting-frequency and depth-selector switches (25–42). Test the continuity of the specified half-sections on the indicated switch positions. In most cases either an a-c or a high-resistance d-c voltmeter, depending on the circumstances, may be used to determine the proper functioning of the switches. Care must be used in measuring voltages on the starting-frequency switch, because the plate circuit (36) of the type 807 keying tube (14) is 1,000 volts, or more, above ground. The highest voltage on the depth-selector switch is 500 volts.

Spare wafers for these switches should be kept on hand. Inspection will show that three different types are used.

(*i*) *Starting motor*.—The squirrel-cage motor winding of the starting motor is on the same shaft with the synchronous motor (47). The starting motor (43) operates on the split-phase principle and is furnished with voltage from the combination of an autotransformer (45) and a 4-microfarad condenser (46). The stator is so connected through the starting-frequency switch (37*L*) that the motor furnishes more torque on the second position of this switch than on the third position. The purpose of the reduced torque is to facilitate the operation of synchronization.

If the starting motor (43) fails to reach proper speed for synchronizing, it may be found that it will do so when the front lid of the indicator cabinet is fully opened.

(*j*) *Synchronous motor*.—The driving motor (47) in the indicator cabinet will synchronize when brought to synchronous speed, if furnished with ample 1025-cycle power. In some cases 0.85 ampere of 1025-cycle current flowing through this motor (as measured after synchronization) is sufficient to ensure that the motor will not drop out of synchronization and stop, while in other cases as much as 1.1 amperes is normally required. If the synchronous motor (47) fails to synchronize after the necessary warm-up period, or if it stops after running a while, the reason may be that the torque required is too great, due to abnormal friction. Something may be touching a moving part or the bearings may need lubrication. All bearings should be lubricated once each year. Turbine oil may be used for this purpose. It should take at least 2 minutes for the synchronous motor to come to a stop after the power is turned off with it at synchronous speed, and most instruments, on the average, require 3 minutes.

(*k*) *Tuning-fork current*.—If no current is flowing through the synchronous motor (47), no 2050-cycle tone from the indicator cabinet will be heard. The trouble may be in the motor itself, in the circuit connecting it to the 1025-cycle power supply, or in the 1025-cycle power supply itself. If the tuning fork (48) fails to vibrate, test the two type 6*C*5 tubes in the tuning-fork circuit (49) and measure the voltage supplied to their plate and grid circuits, comparing the values with those given in table 18. Also test the various related circuit elements. The tuning-fork circuit (49) is rather critical with respect to grid voltage. The value given in table 18 is only an average figure, and some circuits may require a different value. When the grid bias is properly adjusted, the tuning fork (48) will always start vibrating and continue indefinitely, neglecting other considerations, and the grid-bias voltage should be adjusted with this criterion solely in mind. The presence of magnetic or other foreign particles in the air gap between the fork tines and the electromagnets may prevent the vibration of the tuning fork. The tines of the fork (48) should be centered roughly with respect to the driving magnet. The angular orientation of the pick-up magnet has some influence on the starting of the tuning fork but should not be moved more than about 10° from the original angle, and should be readjusted only when other means fail to cause the fork consistently to start vibrating when the voltage is applied. The pick-up magnet should not be adjusted in order to change the current through the synchronous motor (47).

If the fork is vibrating, but there is no 1025-cycle output voltage, test the type 6*F*6 tube, measure voltages supplied to its plate and screen, comparing the values with those given in table 18. Also measure the high voltage supplied to the plates of the two type 838 power-amplifier tubes, as well as the various circuit elements associated with all three tubes (50).

If the synchronous motor (47) fails to synchronize, or if it drops out of synchronism and stops due to insufficient 1025-cycle current, test the tubes and voltages in the power-supply assembly (50). Then if necessary, the 1025-cycle current may be increased by increasing the voltage supplied to the plates of the type 6*C*5 tubes (49) which drive the tuning fork (48). However, the current through the synchronous motor must be kept at a minimum to avoid possible damage due to excessive heating in the indicator cabinet.

(*l*) *Echo amplifier*.—Test the tubes and circuit elements of the specified echo amplifier. Test the voltages supplied to the tubes and compare them with the values given in table 18. Test the insulation of the input and output circuits.

The 17.5-kc echo amplifier (51) must be retuned periodically. This may be accomplished in several ways. One of the most direct methods involves the use, for tuning purposes, of the type 59 tube 17.5-kc oscillator (55) in the 17.5-kc power supply, and the use of the 1-milliampere d-c meter on the face of the echo-amplifier cabinet as a means of tuning indication.

If the 17.5-kc echo amplifier (51) is nearly tuned, only a very small value of 17.5-kc signal voltage will be required, and in all probability, sufficient signal will be picked up by the echo amplifier when the type 838 and type 807 tubes (56) are removed from the 17.5-kc power supply. As in tuning most high-gain amplifiers, care must be exercised to avoid overloading in any of the stages. The second detector stage begins to overload below about 0.75-milliampere plate current, as registered by the 1-milliampere d-c meter. Hence the value of the 17.5-kc input signal and the gain of the echo amplifier must both be kept adjusted so that the tuning may be done with this meter reading between about 0.75 and 0.8 milliampere. Various means of adjusting the value of the signal picked up by the echo amplifier will suggest themselves, and the range of gain control of the amplifier may be temporarily increased, if necessary, by adding resistance to the gain-control circuit in the indicator cabinet. Normal procedure is followed in tuning the amplifier, using the minimum reading of the meter as an indication of tuning for any given tuning operation. The type 59 tube 17.5-kc oscillator (55) may be caused to oscillate continually when the starting-frequency switch is on position 4, by turning off the switch provided inside the indicator cabinet for controlling the 110-volt 60-cycle current supplied to parts within. But this should be done only after the type 838 tubes have been removed from the 17.5-kc power supply.

For tuning the echo-listening channel (52) of the 17.5-kc echo amplifier (51), an oscilloscope may conveniently be used as a tuning indicator. For this purpose the oscilloscope may be connected in place of the head receivers. With the type 59 tube 17.5-kc oscillator (55) still oscillating continuously and with the types 838 and 807 amplifier tubes (56) removed, the audio beat-frequency oscillator should be adjusted to produce an audio frequency of about a thousand cycles. Normal practice is then followed in tuning the 350-kc intermediate frequency transformer in the audio channel.

(*m*) *17.5-kc transmitter*.—Measure the 17.5-kc current flowing into the transceiver (61) by pressing the test button provided for the purpose on the upper panel of the power supply. Test the type 59 tubes in the 17.5-kc oscillator (55). Measure all related voltages in the oscillator and amplifier stages (56) and compare the values with those given in table 18. Test all associated circuit elements including the insulation and continuity of the output transformer.

The 17.5-kc output current is to some extent a function of the keying-circuit adjustment, which is described in (c). The lack of high-voltage d-c (57) may be due to failure of transformers, rectifier tubes, or condensers in the rectifier circuit; or due to failure of the

time-delay relay. The high-voltage 0.02 microfarad noise-suppressing condensers across the rectifier tubes may short-circuit, causing the line fuses to blow out, or they may open-circuit, in which case strays will be registered on the indicator dials at normal gain of the 17.5-kc echo amplifier (51). Strays will also be caused by faulty type 807 tubes (56), particularly when the screen voltage on these tubes is much over 200 volts. Also if the 17.5-kc oscillator (55) is too near the point of oscillation due to improper adjustment of the keying circuit (par. (c)), spurious signals may be transmitted. Such spurious signals and the resultant echoes, when registered on the indicator dials, may appear as strays because of the irregularity of transmission.

(n) *Sonic transmission and reception.*—If the 525-cycle motor generator (58) fails to start when the starting-relay circuit is completed by the starting-frequency switch (41*L*) on position 5, measure the voltage across the switch points involved and the 110-volt d-c ship supply line. Test the d-c line fuses and the starting relay.

If the motor generator (58) is operating and the keying relay is functioning properly but no signal is transmitted, test the fuses protecting the specific type 324 oscillator (63) which is connected. There are normally two of these oscillators, each separately tuned electrically, and when sounding in deep water they may be used interchangeably. However, in shoal water, if they are located at different distances from the hydrophone (64) used, the separation factor (see **556**) will be different for each. And if the draft of each oscillator is not the same they cannot be considered interchangeable for shoal-water sounding.

The selection of these oscillators (63) is made by means of switches on the 525-cycle power-supply panel. Each oscillator is separately tuned by series condensers. The value of the series capacitance in either case should be adjusted to give the maximum transmitted signal intensity at the optimum frequency. This value of capacitance may be assumed to be that which results in a maximum current flowing into the oscillator at the optimum value of frequency.

The strength of the echo signal may be increased by adjusting the frequency of the electric current through the oscillator (63) to the optimum value. This adjustment is made by regulating the speed (59) of the motor generator by means of a rheostat in the field circuit of the generator, or by adjusting the governor on the motor generator if it is so equipped.

If the keying relay (60) is not functioning properly, make the necessary adjustments as described in (*d*).

(o) *Polarizing circuit for the transceiver.*—Note the reading of the meter measuring the d-c polarizing current supplied to the transceiver (61). If the value is not approximately 1.7 amperes, test the various elements in the polarizing-current rectifier circuit (62). Test the insulation of the transceiver (61) and connecting line after disconnecting the latter from the filter-junction box.

Faulty operation of the copper-oxide rectifier, or faults in the other circuit elements and the connections (62) may cause strays to be registered on the dials of the indicator.

(p) *Alternate hydrophones and oscillators.*—If the hydrophone (64) is possibly at fault, try the alternate one provided. If the 324 oscillator (63) is suspected, try the alternate oscillator. The tuning of these oscillators is discussed in (*n*).

(q) *Electric machinery noise.*—A turbogenerator or a rotary converter (65) is used to furnish the 110-volt 60-cycle power necessary to operate the Dorsey Fathometer No. 3, and must be started before the instrument can be operated. If the collector rings on the generator (65) become irregular due to wear, sparking at the brushes will result. Sparking will also be caused by excessive vibration of the brushes bearing against the rings. Such sparking, if aggravated, will cause strays to be registered on the dials of the indicator. The collector rings should be kept clean and should be turned down when necessary. And the brushes should fit properly in the brush holders.

If a noisy 110-volt d-c ship supply (66) is used as a source of power to operate the sonic amplifier (53), strays may be registered. Similarly if the sonic amplifier (53) is operated from a noisy source of 110-volt 60-cycle power (67), such as an inverter or a generator with rings and brushes in poor condition, strays may be registered.

(r) *Acoustic and electric noises.*—As indicated in (*q*), noise causing the registration of strays on the dials of the indicator may be of an electric nature. Such noises may originate in any of the various parts of the instrument. The isolation of the source of electric noises is accomplished simply by disconnecting or turning off the various parts. If the source is found to be located in the circuits (18, 19, 20) which cause the index neon tubes (15, 16, 17) to flash, refer to (*f*) and (*g*). If the electric noises originate in one of the echo amplifiers (51 or 53), this fact may be determined by grounding the input terminals, assuming the fault is not in the circuits causing the neon tubes to flash. If the strays persist, the trouble is in the amplifier and may be due to oscillation or to faulty tubes, parts, or insulation, particularly of the input and output circuits. If the strays are caused by voltage picked up by the supersonic amplifier (51) from the 1025-cycle power supply (50), this will be indicated by a stationary pattern of registration on the 20-fathom dial when the driving motor (47) is running at synchronous speed, and may be proved by removing one of the type 6*C*5 tubes from the tuning-fork circuit (49).

If the noise is found to originate in the hydrophone (64) or the transceiver (61) circuit, and is found not to be caused by disturbances of an electric nature, the source must be of an acoustic nature and will be found within the vessel itself, or in the water. If the noise is not due to the propulsion and passage of the vessel through the water, it may be caused by the main engines, the auxiliaries and appurtenances such as pumps, or by members of the crew chipping paint or making repairs.

## 527. Veslekari

The Veslekari echo-sounding instrument is a graphic-recording type designed for hydrographic surveying in moderate to deep depths. This instrument is made by Henry Hughes & Son, Limited, of London, England. The useful sounding range is from 7 to 1,000 fathoms. Two Veslekari instruments are in use on Coast and Geodetic Survey ships in 1942.

The entire system is composed of five separate units. They consist of the recording mechanism and echo amplifier together in one cast-metal housing, battery compartment and charging panel, contactor box, the magnetostrictive transmitting unit, and a similar receiving unit. The front of the compartment containing the recording mechanism is hinged to give access to its contents, and the echo-amplifier equipment is mounted on the inside of a removable panel to make it accessible.

### *5271. Recorder Cabinet*

The fathogram may be viewed through a removable glass panel on the front of the recorder cabinet. Gain controls, phasing dials, meters, and other controls are located on the front, and additional controls are located on both the left and right side of this cabinet. The principal parts of the recording device and their functions may be described briefly as follows: A starch-iodide paper is used for recording, which is previously dampened by passing over a wick. A stylus passes back and forth across the paper with a linear motion, being in contact with the paper only when moving from left to right, when it is in position for recording. The paper has no printed scale, but passes under a metal scale that is graduated from 0 to 142 fathoms. The electric current from the echo amplifier, caused by the reception of the transmitted and echo signals, flows from the stylus through the paper to a metal platen over which the paper is passing, resulting in dark stains on the paper at such points. The paper moves vertically downward under the stylus at a constant rate, fed by rollers driven by an electric motor. A d-c motor, whose speed is governor-controlled, furnishes the power to operate the stylus, move the paper, and operate the various keying cams.

The keying mechanism can be operated in 11 additional positions, or phases, to advance the keying by steps of 100 fathoms, thus making it possible to record any depth between 0 and 1200 fathoms at the original enlarged scale. For example, for sounding in depths of 450 fathoms, the phasing control should be on position 4. This will advance the keying so that it occurs at a time equivalent to 400 fathoms in depth before the stylus reaches the zero of the fathogram, and when the stylus reaches the equivalent of 50 fathoms on the paper, the echo arrives and is recorded.

In normal operation one signal is transmitted for each cycle of the stylus, or one signal in approximately 1 second; however, by a switching device it may be operated so that a signal is transmitted at only every third cycle of the stylus, or one signal in approximately 3 seconds. (See also **5555**.) When one signal per second is transmitted it should be noted that an echo trace will be recorded at intervals of 400 fathoms and on three different phases of the instrument; for example, if the actual depth is 150 fathoms, a record will be made at 150 and also at approximately 550 and 950 fathoms. Therefore, if the instrument is started in deep water it is essential to operate it first so that it transmits only one signal each 3 seconds until the correct phase has been determined. With one transmitted signal per second there will also be a band of interference at multiples of approximately 400 fathoms, where the echo of a preceding signal and a transmitted signal record at approximately the same place on the fathogram.

Other controls and mechanism in the recorder automatically mark a continuous reference line near the left edge of the paper to represent the zero of the scale, and make a time reference mark once a minute on the fathogram. The following are also provided: a fix-marker button to make a reference mark across the record at any desired time, an electric pencil for recording notes on the fathogram, and a connection to the ship's log for recording the ship's run on the record. (See also **5544**.)

### *5272. Contactor Box*

The principal function of the contactor box is to furnish the necessary energy to operate the magnetostrictive transmitting unit. A 4-microfarad condenser is charged to 1,000 volts by means of an induction coil, from power furnished by the ship's 110-volt direct current. A relay, operated from the keying cam in the recorder cabinet, discharges this condenser into the magnetostrictive transmitting unit.

### *5273. Magnetostrictive Units*

The magnetostrictive units (see fig. 109) for the Veslekari are nickel cylinders about 5 inches long, built up from a great number of laminations which are a few thousandths of an inch thick. These laminations are annular in shape, the outer diameter being 4⅞ inches and the inner diameter 3¼ inches. A toroidal coil *B* of 23 turns of insulated wire is wound around the cylindrical stack in such a way that the nickel laminations are in its field. The wires pass through holes close to the outer periphery of the cylinder, in order that they may not interfere with the acoustic radiation from the outer surface of the cylinder. The axes of these holes are parallel to the axis of the cylinder (fig. 109).

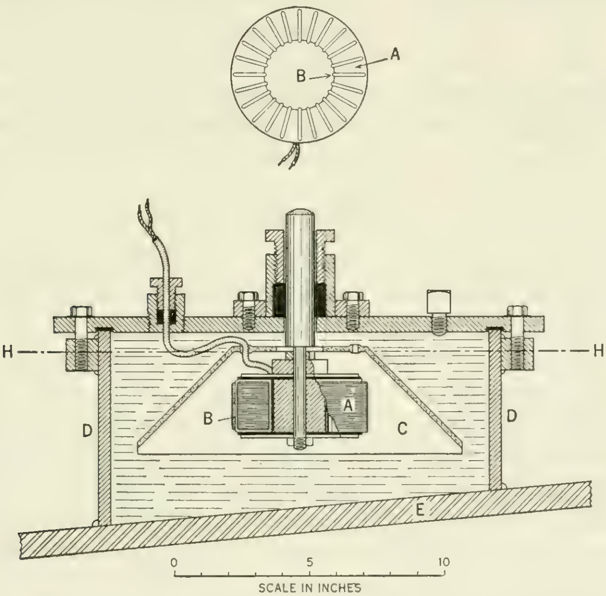


FIGURE 109.—Magnetostrictive acoustic unit. *A*. Magnetostrictive element. *B*. Toroidal coil. *C*. Double walled cone reflector, filled with sponge rubber. *D*. Water-filled tank. *E*. Hull plate. *H-H*. Draft line.

The magnetostrictive units vibrate at a rate of 16000 cycles per second. The principle of this vibration is explained in **5161**B. The vibrating outer cylindrical surface of the transmitting unit is the source of acoustic energy in this case, since only the vibration in a radial direction is utilized.

Surrounding the magnetostrictive cylinder is a spun-metal truncated cone *C*, which acts as a reflector. It is double walled, the cavity being filled with sponge rubber. The angle of slope of the cone is 45° so the energy radiated horizontally by the magnetostrictive cylinder is reflected at 45° from the cone's inner surface and directed downward parallel to its axis. In this way all the radiated energy from the cylinder is in phase at the opening of the cone, and the greater part of the energy of radiation is concentrated within an angle of 30°. The magnetostrictive elements and their reflectors are installed in a water-filled tank *D* fastened to the inside skin of the ship. The acoustic energy of the transmitting unit passes through the ship's steel hull and is directed toward the sea bottom. The dash line *HH* in figure 109 represents the effective draft level of the unit (see **5512**).

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The reverse takes place in the receiving unit. The transmitting and receiving magnetostrictive units are identical, except that the driving coil of the transmitting unit is divided, the two halves being connected in parallel, but in the receiving unit this is a single undivided coil whose inductance is approximately eight times that of the transmitting unit. The nickel of the receiving unit is permanently magnetized by direct current being occasionally passed through the coil for a fraction of a second.

The oscillation period of these magnetostrictive units is determined by their physical properties, the frequency being inversely proportional to the mean annular diameter and directly proportional to the velocity of sound in the magnetostrictive material. Discharge from the condenser into the coil of the transmitting unit sets up a field that causes the magnetostrictive cylinder to oscillate at its natural period. After excitation ceases, the oscillations die away after only a few cycles, because of loss of energy to the surrounding medium (water). The receipt of an echo signal causes a small change in the radial dimension of the receiving magnetostrictive unit, which in turn induces an electromotive force in the toroidal coil. It is this electromotive force, after amplification, that produces the record of the echo on the fathogram.

## 528. HUGHES MS 12 D

The depth recorder *MS* 12 *D*, manufactured by Henry Hughes & Son, is a semi-portable graphic-recording instrument designed for hydrographic surveying in shoal to moderate depths from a small vessel. It is used by the Coast and Geodetic Survey for launch hydrographic surveys. Its depth range is from 3 feet to 100 fathoms.

This instrument is composed of three units; a recording device, the transmitting and receiving units, and the batteries to furnish the necessary operating energy.

The recording device is housed in a cast-metal cabinet containing the echo amplifier, recording mechanism, equipment for producing and timing the transmitted signal, and the necessary operational controls. The record is made on a predamped, starch-iodide paper that moves under the stylus at a constant rate. The stylus is carried at the end of a radial arm that revolves at constant speed. When the stylus is passing over the paper, the echo is recorded by the passage of an electric current from the stylus through the paper, causing a chemical change that leaves a dark stain on the surface of the paper.

The instrument may be used to record in either feet or fathoms by the operation of a control that changes the speed of the stylus and paper by a factor of six, the depth range across the paper being respectively 60 feet, or 60 fathoms. Furthermore, the range may be increased by 40 by means of a control that advances the keying position by that amount.

The speed of the operating motor is controlled by means of a centrifugal governor. A low d-c to high d-c motor generator furnishes the energy for the magnetostrictive transmitting unit. This energy is released from a charged condenser to the transmitting unit by means of a cam that closes a contact once each revolution of the stylus arm. Two pentode-type thermionic tubes are employed in the echo amplifier, whose only selective circuit is the input transformer which is tuned to the operating frequency (about 16 kc). Output voltages of the amplifier are converted to direct current by means of a copper-oxide rectifier, and it is this current that passes through the stylus and paper to make the record.

Transmitting and receiving magnetostrictive units are installed in a streamlined stainless steel housing. The entire unit is secured to the launch in such a way as to offer the least resistance to the water, resulting in the least turbulence and aeration.

The magnetostrictive transmitting and receiving units are similar in design to those of the Veslekari graphic-recording instrument (see fig. 109), except that they are of less cylindrical length and the reflectors are smaller. All required power is furnished from a storage battery of about 200 ampere-hour capacity.

### 529. Bludworth Depthometer

The echo-sounding equipment manufactured by Bludworth Incorporated of New York was designed specifically to meet the requirements of the United States Corps of Engineers in their surveys of inland waterways, dredged channels, and other areas of comparatively shallow depths. This is a recording type of instrument, model *ES*–1000. It is not portable.

Separate magnetostrictive transmitting and receiving units are used, similar to those of the Hughes *MS* 12 *D* (see **528** and **5273**). These units may be installed inside a steel hull in a waterfilled compartment, their signals penetrating the hull plates, or a streamlined housing containing the units may be supported outboard. The inside installation cannot be used with a wooden hull, unless a hole, closed by a metal plate or diaphragm, is cut in the hull. The transmitting unit is shock-excited by condenser discharge, a gas-filled trigger tube furnishing the relay action for discharge.

The echo amplifier uses three thermionic tubes with adequate filtering to permit the passage of the frequency at which the magnetostrictive transmitting and receiving units are tuned.

The fathogram is made on a facsimile type of paper with a printed scale, by means of a stylus carried on a rotating disk. Four different paper speeds are provided, 1¼, 2½, 3¾, and 5 inches per minute. The speed of the synchronous driving motor is controlled by a governor that operates on the d-c motor of a d-c to a-c motor-generator set, thus controlling the frequency of the a-c power that runs the synchronous driving motor. The motor speed is registered on a frequency meter that is calibrated in corresponding revolutions per minute.

A phasing control is arranged to permit extending the depth range of the fathogram. The initial phase is 0 to 60 feet, which is the limit of the printed scale. Three additional phase positions add 50, 100, and 150 feet respectively to the initial position.

The recording mechanism, echo amplifier, and numerous controls are all located in a cast-metal cabinet.

This echo-sounding instrument possesses several unique features, as follows: (1) Variable control and indication of driving motor speed, so that adjustments may be made to compensate for the variation in the velocity of sound in water, thus eliminating the necessity for subsequent corrections due to velocity deviations (see **561** and **5616**). (2) Control to correct soundings for height of tide. (3) Control to correct soundings for draft, and squat and settlement (see **551** and **553**). (4) A clock on the face of the recorder cabinet by which the time is recorded on the fathogram at minute and hourly intervals. (5) The travel of the paper is stopped while the stylus is passing over it, thus reducing distortion of the record due to the motion of the paper.

## 53. FOREIGN ECHO-SOUNDING INSTRUMENTS

The fundamental principles of operation of echo-sounding instruments of European manufacture are the same as for those made in the United States, the principal differences being the manufacturing methods peculiar to each country and the types of the

component parts that constitute the instrument. Graphic recording and the use of supersonic frequencies were pioneered in Europe, with the result that there is a more extensive application of them there. Visual types of echo-sounding instruments are also manufactured in Europe, but are used to a lesser extent.

## 531. French Instruments

A prominent French manufacturer of echo-sounding instruments uses the trade name S.C.A.M. (Société de Condensation et d'Applications Mécaniques). Both visual and graphic-recording instruments intended for use in navigation and surveying are manufactured. One feature common to the instruments manufactured by this company is the use of high supersonic frequencies produced by means of the piezoelectric properties of quartz crystals. This type of acoustic transmitting and receiving unit is described briefly in **5161**C, and is illustrated in figure 98. Electric energy to excite the quartz-crystal transmitting unit is furnished by a low-voltage d-c supply connected to the primary of a step-up transformer. The keying circuit interrupts the current flowing in the primary circuit of this transformer, inducing a high voltage in the secondary circuit. Through appropriate connections this voltage excites a tuned circuit whose frequency is the desired emission frequency. The oscillations set up in this circuit are transmitted to the quartz-crystal transmitter, whose vibrations produce a train of damped acoustic waves in the water. The frequencies of the transmitting and receiving units of the various S.C.A.M. instruments are from 29 to 65 kilocycles.

### *5311. Langevin-Touly Electrolitic Recorder*

The Langevin-Touly electrolitic recorder is one of the standard instruments made by S.C.A.M. The depth is recorded graphically on a moist electrolitic paper that passes under a cam-operated stylus. The stylus moves at a uniform radial rate across the paper in an arc from left to right, and returns by a very rapid reverse movement. The acoustic signal is transmitted at the beginning of the left-to-right movement, the echo registering on the paper during this travel. Some of the principal features of this recorder are:

(*a*) A depth range from 3 to 300 meters, with successive additional phases of 300 meters each.
(*b*) The graduations of the depth scale are marked directly on the fathogram by means of a multi-division brush.
(*c*) The use of high supersonic frequency produced and received by quartz-crystal units.
(*d*) A recording mechanism operated by a 7-volt motor operated from an 8-volt storage battery.
(*e*) A paper speed of 36 inches per hour, one roll of paper lasting 40 hours.
(*f*) An attached magnifying glass to aid in scanning the fathogram.
(*g*) A motor speed indication by means of a stroboscope.

### *5312. Echometre*

The indicating device of this instrument operates in a manner similar to a string galvanometer. A beam of light falls on a small mirror and the echo voltage operates an electromagnet which rotates this mirror through a small angle, causing a vertical deflection of the light beam. After reflection from this mirror, the light strikes another mirror which rotates at a constant rate about a vertical axis for a few degrees in one direction, returning in the opposite direction very rapidly to the starting point. The light reflected from the second mirror falls on a translucent scale which is graduated in fathoms, or meters, or both. The spot of light thus travels from left to right across the depth scale at a constant rate. On reception of the transmitted and echo signals the first mirror deflects this spot of light vertically, and at such points the light forms a peak rising above the base line of light, adjacent to the scale. The signal is transmitted at the beginning of the left-to-right travel of the light spot. Some of the features of the Echometre are:

(*a*) A sounding range from 3 to 660 meters.
(*b*) The use of a high supersonic frequency, the signal being produced and received by quartz-crystal transmitting and receiving units.
(*c*) The depth-indicating mechanism, echo amplifier, and high-frequency generating equipment to energize the transmitting unit all in a single cast-metal cabinet.
(*d*) The visual indicating device operated by a spring-operated clock motor whose speed is controlled by a governor.
(*e*) A ratchet wheel that rotates a mirror horizontally by means of a pawl at a constant rate in one direction and releases the pawl at a determined point to let the mirror and pawl snap back to the starting point.
(*f*) Soundings taken at the rate of six every 7 seconds.
(*g*) A circuit that permits listening for the echo.
(*h*) The type of bottom is approximately indicated by the shape of the echo trace on the indicator.

### *5313. Echoscope*

The Echoscope is a visual depth-indicating device designed especially for sounding in shoal water. Like the Echometre, the depth-indicating device operates on the principal of the string galvanometer oscilloscope and, except for minor differences in the optical system, the indicating mechanisms of these instruments are quite similar. The principal features of this instrument are:

(*a*) A depth range of 1 to 60 meters.

(*b*) The use of high-frequency supersonic signals.

(*c*) The instrument is portable, intended for shoal-water sounding from small boats.

(*d*) Use is made of a single quartz-crystal acoustic unit for both transmitting and receiving. This unit may be supported over the side of the vessel or installed in its hull.

(*e*) The depth-indicating device, echo amplifier, and high-frequency generating equipment for energizing the transmitting unit, all in a single cast-metal cabinet.

(*f*) An indicating device run by a spring-operated clock motor.

(*g*) All electric energy derived from batteries.

### *5314. S.C.A.M.–Touly*

The depth-indicating part of this echo-sounding instrument is quite similar to the visual-indicating instruments made in the United States. The indicating mechanism is housed in a metal box in whose face a circular opening is cut, concentric with which is a graduated depth scale. Adjacent to and just behind the scale is a rotating mirror carried on a radial arm. Light from a stationary neon tube falls on the mirror and is reflected to the depth scale in such a way that a band of light indicates the depth. The operation is as follows: As the rotating mirror passes the zero point on the depth scale, a cam-operated switch causes the transmitting unit to be energized. From this time until the echo is received the neon tube is not illuminated, but when the echo returns the neon tube flashes and remains illuminated until it is extinguished at the zero of the depth scale. The beginning of this illuminated arc is the measured depth. Some of the features of the S.C.A.M.–Touly instrument are:

(*a*) The use of high-frequency supersonic signals.

(*b*) A depth scale graduated from 0 to 400 meters.

(*c*) All operating energy derived from batteries.

(*d*) The driving motor speed controlled manually.

(*e*) A belt-driven centrifugal tachometer indicates motor speed by means of a needle moving over a scale.

(*f*) A manually operated button by means of which transmission is suppressed at will; as, for instance, when it might interfere with the reception of the echo when the depth is near 400, 800, 1,200 meters, etc.

## 532. ENGLISH INSTRUMENTS

Henry Hughes & Son, Limited, of London, England, manufactures a large variety of echo-sounding instruments. This company makes both graphic-recording and visual instruments, utilizing both sonic and supersonic frequencies. Some of the instruments are portable and some require permanent installation. These instruments may be broadly classified as:

(*a*) A graphic-recording instrument that makes use of sonic frequencies, the sound being produced by a hammer or striker. This instrument is intended for use in moderately deep water and is known as the Challenger type.

(*b*) The graphic-recording instruments of the *MS* class that make use of supersonic frequencies, produced and detected by means of magnetostrictive units. A variety of instruments of this class is made, varying in maximum scale range from 70 feet to 4,500 meters. Some of these instruments are portable, but others are for permanent installation.

(*c*) A visual-indicating instrument.

### *5321. Sonic Recording Instrument: Challenger*

The graphic-recording sonic instrument contains the following features:

(*a*) The sound is produced by a hammer or striker.

(*b*) The echo is recorded on sensitized starch-iodide paper.

(*c*) A scale range of 250 fathoms with five phasing positions of 0, 200, 400, 600, and 800 fathoms, which values are added to the recorded soundings.

(*d*) The recording mechanism and echo amplifier are housed in a single cast-metal cabinet.

### *5322. Graphic-Recording Instrument: MS Class*

All the *MS* type graphic-recording instruments record on a moist starch-iodide paper. In some models a rotating radial arm carries a stylus that sweeps in an arc across the record paper, while in other models the stylus is moved linearly across the paper at a constant speed, the stylus

being lifted from the paper on its return. Most of the *MS* instruments have one or more phases to extend the depth range.

Toroidal-shaped magnetostrictive transmitting and receiving units are employed with frequencies of 16 kilocycles. These units are described in **5273** and illustrated in figure 109. For portable installations the magnetostrictive units are housed in a streamlined casing, while for permanent installations they are housed in water-filled tanks secured to the inner side of the steel hull of the vessel. Shock excitation from the discharge of a condenser is used to excite the transmitting units. The keying mechanism that brings about the condenser discharge operates in conjunction with the indicating mechanism.

All the portable instruments are operated exclusively by power from dry and storage batteries; but, in addition to batteries, the permanently installed deep-water equipment requires power from the ship's 110-volt d-c source for driving-motor and transmitting-unit operation.

The recording mechanism and echo amplifier are housed in a single cast-metal cabinet. All the controls necessary for operation are located on the front and side of this cabinet.

The echo amplifier consists of two or more thermionic tubes and its input transformer is tuned to the frequency of the echo signal. In the output of the amplifier a copper-oxide rectifier converts the alternating current to direct current before it is applied to the recording stylus.

Two of the *MS* type graphic-recording instruments used by the Coast and Geodetic Survey are described in **527** and **528**.

### *5323. Visual-Indicating Instrument*

The Hughes visual depth-indicating device consists of a rectangular solenoid which rotates at a constant angular velocity proportional to that of sound in sea water. A soft-iron needle is mounted inside the solenoid so that its axis of rotation coincides with the axis of rotation of the solenoid. A pointer that moves over the calibrated depth scale is coupled to the soft-iron needle. As the solenoid is energized by the impulse of the echo, the needle tends to set itself parallel to the axis of the solenoid. The result is that the pointer moves to the position of the rotating solenoid at the instant the echo is received. The remaining parts of the instrument are similar to the equipment previously described.

### *5324. Marconi Company Instruments*

Because of the affiliation between the Marconi Company of England and S.C.A.M. of France, many of the echo-sounding instruments manufactured by these companies are quite similar. The Marconi Company makes visual-indicating and graphic-recording instruments so nearly resembling the S.C.A.M. Echometre and Electrolitic Recorder as not to warrant further description. Quartz-crystal transmitting and receiving units are used similar to those already described in **531** for the French instruments.

In addition to the piezoelectric units, the Marconi Company makes use of magnetostrictive units in certain other instruments. One instrument, called the "Zero to 150-fathom Navigational Equipment," employs the Echometre visual indicator, or an electrolitic recorder, in conjunction with magnetostrictive transmitting and receiving units. Another instrument for use in greater depths incorporates an electrolitic recorder with magnetostrictive units designed to furnish more acoustic energy; the depth range of this instrument is from 0 to 3,000 fathoms.

The magnetostrictive element consists of a 5-inch core composed of a number of rectangular nickel laminations through which the magnetic flux passes, the remainder of the magnetic circuit being completed through a high-permeability nonmagnetostrictive material. The entire unit has the appearance of a core-type transformer, the core of which has a few turns of wire wrapped around it. The ends of the magnetostrictive core act as the emitting surfaces. The sound energy from the ends of the core is directed toward the bottom by means of reflectors. This assembly is installed in a water-filled tank which is fastened against the inside of the hull plates of the vessel, the sound penetrating the plates. Where increased acoustic energy is required for deep-sea sounding the hull plating below the tank is cut and a thin metal plate inserted; in addition, more electric energy is supplied, and fewer turns are wound around the magnetostrictive core. These magnetostrictive units are shock-excited by the discharge of a condenser.

## 533. German Instruments

The echo-sounding instruments manufactured by the Atlas Werke Company of Bremen, Germany, are of the visual-indicating type and employ magnetostrictive units to transmit and receive the

acoustic signals. In appearance and operation the indicating device of this instrument is quite similar to that of the 312 Fathometer which is described in **521**. A neon tube rotating behind the depth scale indicates the depth by its flash. A governor-controlled motor rotates the neon tube and operates the keying cam. The energy to operate the transmitter is supplied by the discharge of a condenser into the coil windings of this unit, thus producing shock excitation to the magnetostrictive elements which in turn set up the acoustic waves in the water. The transmitting and receiving units are installed in strong water-filled tanks, mounted inside the ship's hull as described in **543**, or an opening may be cut in the hull over which the tanks are installed, the opening being replaced by a thin metal diaphragm. The instrument has two depth scales, one from 0 to 100 meters, and the other from 0 to 1,000 meters, selection between which is by means of a switch. A graphic attachment may be used in conjunction with the visual-indicating device and in this way the advantages of both types of instruments may be realized simultaneously.

## 54. ECHO-SOUNDING INSTRUMENT INSTALLATION

Much of the effectiveness of an echo-sounding instrument depends on the installation—not only as to convenience but as to the results obtained. Each type of instrument requires a different installation, which must often be modified for different ships. The general factors to be considered are as follows: (1) The available space for the various parts of the instrument—the indicator must be conveniently located for use in surveying, and all parts should be where they are protected from weather, heat, dirt, and vibration, and they must be accessible for adjustment and repair. (2) The parts should be arranged so that the connecting electric cables can be installed conveniently and where they are not exposed to damage. (3) The transmitting and receiving units should be located where they will be most effective.

Since there is a wide variation in these factors even on ships of the same type, installation procedure can be described only in generalities.

### 541. DORSEY NO. 1 INSTALLATION

The indicating device of an echo-sounding instrument is located in the pilothouse of most survey ships of the Coast and Geodetic Survey. This is the most convenient location for use both in hydrographic surveying and in navigation. The after bulkhead of the wheelhouse is usually a desirable location and affords a rigid support for the indicator cabinet.

The indicator cabinet of the Dorsey Fathometer No. 1 must be located where there is a space on each side which will permit opening the doors, and where there is a sufficient clearance above it so that the photoelectric tube, exciter lamp, and index adjustment are accessible. The echo amplifier should be close enough to the indicator cabinet so that the operator can reach the amplifier gain control and still have a full view of the depth dial. This arrangement is also desirable for electric reasons.

In most cases the equipment can be fastened directly to the deck or bulkhead, but on ships where vibration is excessive, some of the equipment, such as the echo amplifier, must be mounted on vibration-absorbing mounts.

The power supply can be installed in any suitable place in the ship, but the numerous cables between the power supply, indicator cabinet, and amplifier, make it desirable to keep these three units reasonably close to each other. The power supply and echo amplifier should be separated by at least 5 feet to avoid possible electric interference.

The most careful consideration must be given to the location of the transceiver. It should be located where the maximum echo signal to noise ratio is to be expected. This ratio is a function of the impedance to transmission of acoustic waves and the spurious noises generated either in the ship or by the passage of the ship through the water. Aeration and turbulence (**5143**) are causes of both sound attenuation and noise and should be considered when selecting the site for the transceiver. Experience has proved that a point a little forward of amidships is generally relatively free from aeration and turbulence. Farther aft turbulence increases, and farther forward there are likely to be installation difficulties because of the shape of the hull. The transceiver should be located as near the keel as possible, since aeration and turbulence diminish as this point is approached. The engine room and the propeller are usually principal sources of noise, so it is important to place the transceiver a reasonable distance forward of the engine room. It should be at least 10 feet from, and never directly aft of, any discharge or intake pipes, submerged log mechanism, or any other protrusions from the ship's hull.

The transceiver is housed in a cast-steel tank (fig. 105), which can be installed in almost any type of ship, it being only necessary to cast the holding ring of the housing to fit the slope of the ship's bottom at the selected location. The transceiver must be installed so that its diaphragm is parallel to the surface of the water. To reduce turbulence due to the projection of the housing beyond the hull, a streamlined blister of steel plate or reinforced concrete is built around it, or on a wooden vessel it can be made of wood bolted to the hull. As can be seen in figure 105, the transceiver is set in the housing in such a way as to form a watertight bottom, the transceiver's diaphragm being in contact with sea water. Rubber gaskets between the transceiver and housing prevent any part of the transceiver from being in direct contact with metal, to eliminate or dampen the effect of hull vibrations on it. It is important to verify that all these gaskets are in place before the transceiver is installed. The electric cable to the transceiver should be sheathed with a lead or copper covering, or be run in a conduit, where it passes through the bilge, to protect it from oil and water.

Where a filter junction box is used with the Dorsey No. 1, to introduce the polarizing current, it should be located near the transceiver.

Shielded cable should be used between all units. Although multiconductor cables may be used in some cases, the following cables, without exception, should be individually and completely shielded from source to terminus: (1) The 17.5-kc cable from power supply to transceiver; (2) the 17.5-kc cable from power supply to echo amplifier; (3) the output of the echo amplifier to the indicator cabinet; (4) the 1025-cycle cable from power supply to indicator cabinet; and (5) the 60-cycle 110-volt cable to all parts. A high grade of cable suitable for marine use must be employed; only two sizes are needed for the entire installation. The cable between the power supply and transceiver should be shielded, low-capacity, two-conductor No. 10 stranded wire, insulated for 2,000 volts or more. The cables for all other parts may be shielded No. 14 conductor, insulated for 2,000 volts or more.

Where the cables are exposed to possible damage, they should be run through conduits. Kick pipes should be used where they pass through decks or bulkheads. Watertight junction boxes must be used at the unions of two or more cables.

The longer cables should be bonded to the ship at intervals. Where practicable each separate piece of equipment should be directly grounded but, if this is impracticable, the separate cables should be all bonded together with wire and this wire grounded directly to the steel frame of the ship.

## 542. Dorsey Nos. 2 and 3 Installation

All the instructions for installation of the Dorsey Fathometer No. 1 apply equally to the Dorsey Fathometer Nos. 2 and 3, except for the size of the indicator and the installation of the sonic system of the 312 Fathometer to work in conjunction with them.

Since there are differences in the sizes and construction of the indicator cabinets of the Dorsey Nos. 1, 2, and 3, each should be located with due regard to its weight and to affording accessibility to its interior. The Dorsey No. 2 indicator cabinet should be located where there is a free space on each side so that the doors can be opened, while the Dorsey No. 3 requires a space through which the front may be opened through an angle of 90°, as well as clearance above it. Because of its weight, the Dorsey No. 3 indicator cabinet should be supported on its base, in addition to any bulkhead fastenings.

The Dorsey Fathometer Nos. 2 and 3 are combined sonic and supersonic instruments, and since the sonic frequency of 1050 cycles is quite close in frequency to the 1025-cycle frequency of the current of the motor driving the indicating mechanism, there is a possibility of strays, caused by the 1025-cycle current, interfering when the sonic system is used. To guard against this, the 1050-cycle echo amplifier and its input wires must be at least 10 feet from the power supply, the indicator cabinet, and any wires carrying 1025-cycle current. It has been found convenient in some cases to locate this sonic echo amplifier in the ship's hold near the hydrophone tanks.

## 543. Veslekari Installation

The factors governing the location of the indicator cabinet of the Dorsey Fathometers apply also to the Hughes Veslekari graphic-recording instrument. There should be adequate room on each side of the recorder cabinet to permit operation of the various controls, and sufficient space in which to open the hinged front.

The high- and low-voltage batteries to operate the echo amplifier are contained in a box which should be in the vicinity of the indicator cabinet. A charging panel and resistor for charging the low-voltage batteries should be mounted near the battery box. The battery wires to the recorder cabinet should be shielded.

The contactor box which furnishes the energy for the magnetostrictive transmitting unit must be located not more than 15 feet from it. This box should be mounted in a vertical position, in a readily accessible place, and so it is free from vibration. The front cover is hinged, and space should be allowed for it to swing either to the left or to the right sufficiently to make the interior accessible.

The site for the tanks containing the acoustic units should be selected with care. The same considerations apply which were mentioned in **541** in connection with the location of the transceiver and in addition there are other factors to be considered. The transmitting and receiving units should not be so far apart as to introduce an appreciable error in shoal soundings due to their physical separation (see **556**), yet they should be far enough apart to reduce the effect of the transmitted signal on the receiving unit, so that the registration of the transmitted signal will not be unduly prolonged, making shoal soundings impossible.

Tanks to house the magnetostrictive units and associated reflectors are designed to fit the particular ship on which they are to be installed. The selected location, frame spacing, and other constructional details influence their design. The following is an abridged excerpt from specifications for the construction of such tanks installed on two Coast and Geodetic Survey ships:

Tanks to be made of quarter-inch iron, rolled into a cylinder 25 inches long with an inside diameter of 19 inches, and welded along the seam. Tanks to be provided with watertight covers of half-inch iron held down to the tank top by four half-inch brass bolts. No bolts or fittings to be on the inside of the tank. The following holes to be drilled in each cover: (1) center hole, to pass spindle for holding the reflector, must be accurately located on the axis of the tank to make the reflector concentric with the inside of the tank; (2) two holes for watertight glands for the passage of electric cables; and (3) two half-inch tapped holes for filling the tank with water.

Sometimes the transmitting and receiving units are placed on opposite sides of the keel, but not necessarily between the same frames. A separation of 4 to 10 feet is usually satisfactory. The tanks should be located where the slope of the hull plates does not exceed 19°, and the lower edges of the tanks must be shaped to the plates to ensure watertightness and that the sides of the tank are vertical. All cement and paint must be removed from that part of the ship's plates that will form the bottom of the tank. The tanks may be secured to the inside of the hull plates by welding, or by means of a pressure fit. The welding may be on the inside or outside of the tank, but if inside it should not extend into the area of vertical projection of the reflector. To secure the tank by pressure fit a strongback may be used, fitted between the frames and arranged so as to apply vertical pressure on the tank and so press it securely against the ship's plating. A rubber gasket should be used between the lower edge of the tank and the plating.

The receiving-unit tank should be located with the same care required for a transceiver (see **541**), and in addition, this tank should have no direct contact with bulkheads or ship's water tanks. The magnetostrictive units should not be installed in the ship's water tanks, nor should the tanks they are in be located so near the keel that they will be in the bilge water.

Three shielded cables, insulated for 2,000 volts, connect the recorder, contactor box, and the transmitting and receiving units. A three-conductor shielded cable of No. 14 wire runs from the recorder cabinet to the contactor box; a two-conductor No. 12 shielded cable connects the contactor box to the magnetostrictive transmitting unit; and a third cable of the same specifications connects the magnetostrictive receiving unit to the echo amplifier located in the recorder cabinet. These cables should be separated from one another by at least 2 feet, and should all be bonded to the metal frame of the ship at intervals. The cables should pass through stuffing boxes where they enter the transmitting and receiving unit tanks. These tanks must be kept filled with fresh water. If there is danger of the water freezing, Prestone or an equivalent should be added in amount equal to 20 or 30 percent of the water.

### 544. Semiportable Installations

The general procedure for the installation of a semiportable instrument, such as the 808 Fathometer, has been described in **5236**. The same kind of an installation is applicable in the case of the Hughes *MS* 12 *D* recording instrument, making allowance for the constructional differences of the two instruments.

## 545. THE ADVANTAGES OF TWO ECHO-SOUNDING INSTRUMENTS

It has been found advantageous to have two echo-sounding instruments on vessels engaged in extensive hydrographic surveys, so that each may be used to its best advantage and so there will be no loss of time due to instrument failure. Most echo-sounaing instruments are designed to operate to best advantage within a certain depth range and, in addition, some types of instruments will give more detailed information than others, when sounding over irregular bottom.

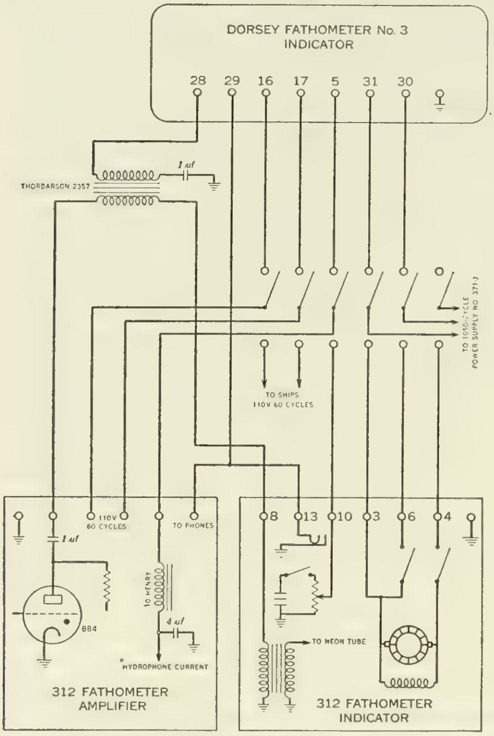

FIGURE 110.—Intercircuit connections between 312 Fathometer and Dorsey Fathometer No. 3.

For surveys in shoal and moderate depths the Dorsey Fathometer No. 1 and the 808 Fathometer have proved a useful combination. Because of its greater accuracy, the Dorsey Fathometer No. 1 is useful when sounding over regular bottom. But where the bottom is irregular, characterized by sudden shoals, rocky bottom, or substrata, the 808 Fathometer is used advantageously, because the fathogram contains a permanent record which may be carefully and deliberately scanned for these features at any future date.

It is common practice to operate both of these instruments simultaneously when sounding, reading the depths on the Dorsey Fathometer and referring to the fathogram for bottom features of special importance or interest that might be missed by the fathometer attendant. The Dorsey Fathometer No. 1 is frequently used for sounding in depths beyond the range of the 20-fathom scale, and instances have occurred in the past where the rapid changes of depth have confused the fathometer attendant so that he added the wrong multiple of 20 fathoms to the dial reading. In such cases the fathogram of the 808 Fathometer is invaluable as a means of verifying the depths.

Another combination of echo-sounding instruments that has proved valuable is the Dorsey Fathometer No. 3 and the Hughes Veslekari. The recording feature of the Veslekari instrument supplements the Dorsey Fathometer in the same way the fathogram of the 808 Fathometer supplements the Dorsey No. 1. In deep water where the bottom is extremely irregular, as in submarine valleys, the soundings of the Dorsey Fathometer operating on the 312 Fathometer sonic system are often difficult to interpret due to multiple reflections from slopes, but the fathogram of the Veslekari instrument will show a pattern of soundings that usually can be analyzed to give a more nearly correct value of the depth. The Veslekari instrument is a useful supplement to the 312 Fathometer for the same reasons.

In order to avoid serious loss of time in isolated regions because of failure of the echo-sounding equipment, a Dorsey Fathometer No. 3 and a complete 312 Fathometer

system have been installed on some vessels. Although the two instruments are not interchangeable as to depth range, they were interconnected so that the 312 Fathometer could be operated independently. Figure 110 shows the circuit arrangement by which the sonic-oscillator and echo-amplifier system can be switched to either the 312 Fathometer or the Dorsey Fathometer. When the switch is down the complete 312 Fathometer system is in operation. When the switch is up, the oscillator and echo amplifier are operated in conjunction with the Dorsey Fathometer, and the soundings will be registered on the dial of the Dorsey Fathometer indicator.

## 55. ADJUSTMENT AND VERIFICATION OF ECHO-SOUNDING INSTRUMENTS

For utmost accuracy all depths measured by echo-sounding instruments must be corrected instrumentally, or otherwise, for certain variable factors and conditions; although, practically, some inherent errors are so insignificant that they may be ignored, or are so nearly constant that an initial adjustment of the instrument may suffice.

Where practicable, compensating adjustments should be made to the echo-sounding instruments for certain factors, so that the soundings as registered will have been corrected by the appropriate amounts. This eliminates a subsequent arithmetical reduction with its possibility of error, and reduces the office time required to complete the records.

Draft (**551**), instrumental error (**552**), and settlement and squat (**553**) are factors for which compensation may be made by an appropriate adjustment of the instrument. The effect of each of these is determined individually and then combined algebraically into a total for which allowance is made by setting the index of the instrument according to **554**.

All echo-sounding instruments in use by the Coast and Geodetic Survey in 1941 are driven by motors which must be maintained at a constant speed, or the registered depths will be erroneous. In some echo-sounding instruments a special test is required to detect a variation in motor speed of appreciable effect, the test varying with the type of instrument. This test must be made periodically to ensure that the instrument operates at the correct speed, and an adjustment must be made if necessary. (See **555**.)

If soundings are obtained with instruments using separate acoustic units for transmitting and receiving, an error due to the horizontal distance between the two units must be avoided by compensation or correction. This is known as the separation error (see **556**).

### 551. DRAFT

The depth of water registered by an echo-sounding instrument used in hydrographic surveying should be the depth below the water surface, and not the depth below the submerged acoustic units. The common method of allowing for the draft of the transmitting and receiving acoustic units, is to delay the transmission of the signal by a time equal to twice that which would be required for the sound to travel from the surface of the water to a depth equal to the draft of the acoustic units, which in turn is equal to a reading of this depth on the dial of the instrument. Draft with reference to echo-sounding corrections shall be understood to be the mean depth of the transmitting and receiving units below the surface of the water when the ship is not underway.

Provision must be made, or special instruments must be installed, to measure the draft on ships having the acoustic units permanently mounted in the hull. An internal

draft gage may be installed by which the draft of the acoustic units may be read directly, or the draft marks on the bow and stern or on the sides of a vessel may be used to find the draft of the acoustic units. A third method involves the use of permanently marked reference points at convenient locations on the main rail or deck of the vessel. In the latter method, knowing the vertical distance of the reference points above the acoustic units, their draft at any time may be determined by measuring the vertical distance of the reference points above the water surface and taking the difference between the two vertical distances.

### *5511. Facilities for Draft Measurement*

The draft of an acoustic unit is the vertical distance from the water surface to some reference point on or in the unit. This point is usually the sound transmitting or receiving surface, which in most cases is a diaphragm. For systems employing separate transmitting and receiving units the draft is the vertical distance to the midpoint of an imaginary line joining these two units. The draft of the acoustic units of echo-sounding instruments employed by the Coast and Geodetic Survey shall be measured from the surface of the water to the following:

(*a*) 312 Fathometer—to the midpoint of an imaginary line joining the center of the diaphragm of the 324 oscillator and center of the hydrophone.

(*b*) Dorsey Fathometer No. 1—to the lower surface of the diaphragm of the transceiver.

(*c*) Dorsey Fathometer No. 3—the same as the Dorsey Fathometer No. 1 for the transceiver, and the same as the 312 Fathometer for the 324 oscillator and hydrophone.

(*d*) Veslekari—to the midpoint of an imaginary line joining the tops of the reflecting cones. The proper point on the top of the cone is in the plane indicated by the line *HH* in figure 109. For the *MS* 12 *D*, measurements should be made to this same plane, although, of course, the cones are contained in a fish.

(*e*) 808 Fathometer—to a point 6 inches below the top of the fish, and not from the bottom of the cover plates.

The draft of an acoustic unit permanently installed in the ship's hull may be determined (1) by measuring the vertical distance from the surface of the water to reference points on the ship's rail or on deck, which are at a known vertical distance above the acoustic unit, (2) by an internal draft gage especially installed for the purpose, or (3) by existing draft marks or gages. A draft gage is usually installed while the ship is in drydock and the required measurements to establish any permanent reference marks may also be conveniently made at this time.

If reference points on deck are to be used, points should be selected on both sides of the ship, preferably on top of the main deck rail, at positions abeam of the acoustic units. These points should be at a known vertical distance above the acoustic unit, or above their mean position if there are separate transmitting and receiving units, and permanently marked for identification, as by metal plates, and their positions and vertical distance above the acoustic units marked on the ship's blueprints. If there is more than one echo-sounding instrument, the plates should contain the data for each.

The measurement of the vertical distance of the reference points above the mean level of the acoustic units, or the measurements to set the zero of the scale of an internal draft gage to the horizontal plane of the acoustic units, may be best made when the vessel is in drydock, with the aid of an engineer's level and a steel tape.

An internal draft gage for use in determining the draft of acoustic units should be installed near the acoustic units and connected to an independent opening through the hull. The gage may consist of a brass pipe connected to the intake, to which is con-

nected by means of a stuffing box, a ¾-inch diameter glass tube, installed vertically with its midpoint at about the normal draft of the ship. The glass tube must be long enough to cover the extreme range of draft. The upper end of the tube should be open to prevent a pressure or vacuum developing above the water in the tube. A gate valve should be incorporated in the lower part of the gage so that the connection may be closed off, except while the gage is being read.

A scale graduated in feet and tenths, with its zero at the level of the acoustic units, should be secured behind the glass tube, so that the level of the water in the glass tube will indicate on the scale the draft of the acoustic units. A few drops of oil, or a small cork ball, may be placed on the surface of the water to aid in reading the draft. The length of the graduated part of the scale need be only long enough to cover the extreme range in draft of the vessel.

The scale of the gage can be set originally by test. With the vessel stationary in calm water, take a series of measurements from the reference marks described above to the surface of the water, compute the draft of the acoustic units, and then set the draft gage scale to this draft. Even though the scale may be adjusted for use with a particular acoustic unit, or pair of units, it may also be used for the draft of other acoustic units in the vessel, by applying an allowance for the difference in draft of the units. A sufficient number of comparisons must be made over the normal range of the draft of the vessel caused by light or heavy loading.

Draft marks on the stem and stern of a ship, or internal draft gages installed on some ships, to indicate the ship's draft, also may be used to determine the draft of acoustic units once the correct relationship has been determined. The marks or gages usually indicate the depth of the keel below the water surface at their positions. If the horizontal distances between the draft marks, or gages, and the acoustic units and their vertical relationship are known, the draft of the acoustic units may be found by simple proportion. A scale diagram of these relationships may be prepared and used to find the draft of the acoustic units graphically from the gage or draft-mark readings.

### *5512. Measurement of Draft*

To determine the draft of the acoustic units from reference points on the ship's rails, the distance between these points and the surface of the water must be measured accurately. Accurate leadlines marked in feet and half-feet or light wooden rods with a scale in feet and tenths may be used for the purpose. The measurements should be made on both sides of the ship simultaneously while the ship is stopped and preferably where the sea is calm. Several measurements should be made. Each pair of measurements should be meaned and the average of the pairs subtracted from the vertical distance between the reference points and the acoustic units. The result will be the draft of the units.

To determine the draft of the acoustic units from an internal draft gage, it is only necessary to open the gate valve and allow the water to seek its level in the glass tube and then read the draft at the water level from the graduated scale. The ship must be stopped while taking the measurement. The observer's eye should be at the level of the water surface. After the draft has been measured the gate valve should be closed.

For sounding in depths of less than 10 fathoms the draft should be measured to the nearest quarter-foot.

The draft of the acoustic units must be recorded in the Sounding Record in the appropriate space in rubber Stamp No. 33, Sounding Apparatus (see fig. 176). This stamp provides a separate entry for the draft of the oscillator and the hydrophone used. Where a transceiver is used, or where it is more convenient to determine the mean draft of the transmitting and receiving units, the one entry will suffice if the facts are clearly indicated.

If there are separate transmitting and receiving units, it is their mean draft which is used for the purpose of draft adjustment.

### *5513. Frequency of Draft Measurements*

The variation in the ship's draft and the depth of the soundings are the two factors which determine the frequency of draft measurements.

For soundings of 10 fathoms or less the draft should be known within one-fourth foot and should be measured with sufficient frequency to ensure this. Depending on the variation in the ship's draft, this may require a measurement once each day, usually at the beginning of the day's work, so that the echo-sounding instrument may be adjusted before any soundings are taken.

For soundings deeper than 10 fathoms the draft should be known within at least one-half percent of the depth of water.

For soundings in deep water where the possible error due to erroneous draft adjustment is only a very small percentage of the total depth, an accurate knowledge of the draft is unimportant and echo-sounding instruments are usually adjusted for a mean draft.

## 552. Instrumental Error

Errors caused by instrumental time lags are inherent in all echo-sounding instruments, and some have mechanical lags. Their effect on echo sounding is to increase the registered depth to a value greater than the actual depth. Such errors differ in magnitude for each type of instrument, and are unlikely to be exactly the same even for instruments of the same design. Furthermore, such errors are variable in which changes may be attributed to: (1) Variation of tuning and gain of the echo amplifier; (2) variation in strength of the transmitted and echo signals; (3) adjustment of the keying circuit; and (4) deterioration of tubes and other parts. There are numerous other minor causes of such errors, but they are usually of small magnitude, and are relatively constant and therefore need not be considered for correction purposes.

Perhaps the most troublesome source of instrumental time lag is that due to a variation in the strength of the registered echo signal. As its strength decreases, the value registered on the dial increases and is always too large. This may be the result of varying the gain of the amplifier or of a variation in the strength of the received echo signal before amplification. A variation in the gain of the amplifier affects the registered depth and it has been repeatedly emphasized in this Manual that the amplifier must be operated at the highest gain practicable without introducing too many strays. A reduction of gain may increase the registered depth by an appreciable amount. (See **5163** and **5237**.) The variation in the strength of the echo signal before amplification is complex—it is partly a function of depth but may be due also to the character of the bottom or the characteristics of the water. This latter variation cannot be compensated for by a simple instrumental adjustment, but if the range of depth in the project area is limited, this error is small as compared to other errors.

Although the above-mentioned errors are variable to a certain extent, most of the variations are small compared to the total amount, and the important changes are gradual. The various instrumental lags are principally additive, and their sum may be of such a magnitude as to require instrumental compensation or an arithmetical correction to the soundings. For correction purposes these errors are combined with other unknown quantities, the total being called the instrumental error, which is determined periodically and compensated for instrumentally. It is especially important that this be done where the survey includes precise sounding in shoal depths.

### *5521. Determination of Instrumental Error*

The amount of the instrumental error is determined by comparing echo soundings with simultaneous direct vertical measurements of the depth. Such simultaneous depth measurements are usually called *simultaneous comparisons.* The echo-sounding instrument must first be adjusted for the draft of the transmitting and receiving units. A carefully standardized leadline, or wire registering on an accurately calibrated sheave, and a heavy lead must be used for the vertical measurements. The simultaneous comparisons must be corrected—the echo soundings for the velocity of sound, and the leadline or wire soundings for any leadline error or sheave factor. The difference between the simultaneous comparisons after correction, without regard to sign, is the instrumental error. The correction for this error is called the instrumental correction, and may be plus or minus. Where the index has been adjusted to compensate for the amount of settlement and squat while underway (see **553**), that amount must be applied to the observed echo soundings from the stationary vessel to bring the simultaneous measurements to the same plane (see table in **5522**).

If the draft has been properly compensated for, the instrumental correction is the quantity that must be applied to the echo sounding corrected for velocity, to make it agree with the depth measured by leadline or wire. This is accomplished instrumentally by adjusting the index for the amount of the instrumental correction.

Although some types of echo-sounding instruments may require special consideration when the instrumental error is determined, the general procedure is essentially the same for all instruments that have acoustic units permanently installed in the ship's hull. This general procedure is as follows:

(1) Operate the echo-sounding instrument for at least one-half hour before use.

(2) Set the amplifier gain at the value normally used when surveying—not necessarily at the value to give best results in the depth in which the test is made.

(3) The ship must be stopped, or at anchor, where the bottom is level and comparatively hard, and preferably in a depth not exceeding 25 fathoms. The sea should be moderately smooth so the ship will have little or no vertical motion, and so that the vertical casts will be accurate.

(4) Determine the draft of the acoustic units in accordance with **5512** and adjust the instrument so that the index will compensate for the draft.

(5) A minimum of five simultaneous comparative soundings should be taken. The echo soundings should be read by the operator without a prior knowledge of the depths obtained by direct measurement; each sounding should be read at the instant the lead strikes the bottom. The shoal edge of the neon tube flash or other registration should be read. The leadline or wire soundings should be taken from a position as near the acoustic units as practicable and extra care must be taken to ensure their verticality.

(6) Correct the echo soundings for the velocity of sound by one of the methods explained in **561**, and for settlement and squat if the index has been previously adjusted to compensate for this. Correct the leadline or wire soundings for errors of graduation, or calibration. The difference between the corrected vertical measurements and the corrected echo depths is the instrumental error or the amount for which compensation must be made.

For echo-sounding instruments, especially those with outboard acoustic units, used in launches and small vessels, an alternate method of determining the instrumental error is by means of the bar check which is described in **557** and **5571**. When good results can be obtained by bar check, it is the more accurate method and should be used.

### *5522. Record of Simultaneous Comparisons*

Simultaneous comparisons should be recorded in the Sounding Record at the time they are made. Rubber Stamp No. 35 (fig. 178) should be used for this purpose, the uncorrected echo soundings and vertical soundings being entered in columns under the appropriate headings. The computation of the instrumental correction should not be made in the Sounding Record.

Simultaneous comparisons should be tabulated in vertical columns and corrected in standard form, according to the example below. The echo depths are corrected for velocity of sound and settlement and squat; and the vertical measurements for any errors of graduation or calibration. The instrumental corrections, obtained by subtracting the corrected echo depths from the corresponding corrected vertical depths, should be entered in a separate column. The mean instrumental correction for each set of observations is entered in the "Remarks" column.

| Date | Echo depth | | | | Vertical measurement | | | Instrumental correction | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Observed | Velocity correction | Settlement and squat | Corrected depth | Observed | Correction | Corrected depth | | |
| 7-16-41 | 25. 5 | −0. 3 | −0. 2 | 25. 0 | 25. 0 | +0. 1 | 25. 1 | +0. 1 | Fne. wh. S. |
| | 25. 3 | − . 3 | − . 2 | 24. 8 | 24. 9 | + . 1 | 25. 0 | + . 2 | |
| | 25. 5 | − . 3 | − . 2 | 25. 0 | 25. 6 | + . 1 | 25. 7 | + . 7R | Wire leading aft. |
| | 25. 5 | − . 3 | − . 2 | 25. 0 | 24. 8 | + . 1 | 24. 9 | − . 1 | |
| | 25. 0 | − . 3 | − . 2 | 24. 5 | 24. 4 | + . 1 | 24. 5 | . 0 | |
| | 24. 4 | − . 3 | − . 2 | 23. 9 | 24. 1 | + . 1 | 24. 2 | + . 3 | Mean instrumental correction +0. 1. |

The simultaneous comparisons in a project area for a season should be tabulated chronologically and be included with the computations of velocity corrections (see **8332**).

For simultaneous comparisons, when a graphic-recording echo-sounding instrument is used, the depths by bar check, leadline, or wire, should be recorded on the fathogram as well as in the Sounding Record. A mark should be made on the fathogram to identify the exact position of the echo-sounding depth and the corresponding measured depth should be recorded closely adjacent to the mark.

### *5523. Frequency of Determination*

The frequency with which the instrumental error should be determined depends on the operational constancy and stability of the echo-sounding instrument. If the instrument appears to be in perfect working condition and there is no reason to suspect that the instrumental error has changed, a determination made once each week should suffice. But if the instrument is operating poorly and there is reason to believe that the instrumental error varies considerably, it should be determined at least once each

day, and more frequently if necessary. Immediately after an echo-sounding instrument has been repaired, after tubes or parts have been renewed, or after the instrument has been changed in any way, the instrumental error should be determined and correction made for it.

The frequency with which bar checks should be made is prescribed in **557**.

### 553. Settlement and Squat

Although an echo-sounding instrument correctly registers the depth from a vessel when stopped, there is no assurance that the correct depth will be registered when the vessel is underway. This is because a point on the vessel may experience a vertical displacement when the vessel is underway, relative to its position at rest. Acoustic units in a ship's hull are affected by such a vertical displacement, depending on their location. The magnitude of this displacement may be such as to warrant compensation, especially where precise soundings in shoal water are to be obtained from a vessel running at moderate to high speeds. The factors accountable for this vertical displacement are settlement and squat.

Settlement is the general lowering in level of a moving vessel, relative to what its level would be were it motionless. Settlement is due to a regional depression of the surface of the water in which the ship moves. It is not an increase in displacement and, therefore, cannot be determined by reference to the water in the immediate vicinity of the ship.

Squat refers to the change in trim of the vessel when underway. At speeds ordinarily used in surveying, squat manifests itself in a lowering of the vessel's stern and a rise of the bow.

The major factors which influence settlement and squat are hull shape, speed, and depth of water under the vessel. The effect of squat on the draft of the acoustic units is usually not appreciable if they are mounted amidships, or a little forward of amidships, as they generally are. On the contrary, settlement may be quite appreciable at normal sounding speeds. In depths approximately seven times the draft, for a survey ship it will probably amount to about one-half foot and in extreme cases may be as much as 1 foot, increasing slightly as the depth lessens.

The combined effect of settlement and squat at various sounding speeds used, shall be determined for each survey vessel, including auxiliaries and launches, used for hydrographic surveying in shoal or moderate depths. A test to determine this for each vessel should be made at the beginning of each season. The vessel should be carrying an average load and be in average trim. This value may be assumed to be a constant for the season's work. Where the result of the test shows that the combined effect of settlement and squat is less than 0.2 foot, it may be neglected, but if it is more than this, an instrumental adjustment should be made to all echo-sounding instruments used in shoal water to compensate for it.

Where the index has been adjusted to compensate for the amount of settlement and squat at normal sounding speed, it is necessary to make an arithmetical correction to any soundings taken from the vessel while stationary or running at slow speed. (See example in **5522.**)

Two methods may be employed to determine the combined effect of settlement and squat. In both, the tests should be made at either high or low water, when the tide level is varying slowly. Provision must be made to measure any tidal change which does occur during the tests.

The tests should be made at a place where the bottom is known to be smooth and level and in a depth of water which is approximately seven times the draft of the survey vessel. If the survey vessel is habitually used to survey in depths considerably less than this, an additional test should be made at the lesser depth.

*First method:* A leveling instrument may be mounted on shore, preferably on the end of a pier off which are the required conditions as to depth and bottom, and past which the vessel can run at normal sounding speed. A marker buoy should be anchored with a short scope at the point where the test is to be made.

With the vessel stopped at the marker buoy, a level rod is held on board the vessel vertically over the transmitting and receiving units, or over midway between them if one is forward of the other, and the level rod is read with the instrument on shore. The height of the tide should be noted. Then the vessel should run past the marker buoy at normal sounding speed, with the rod held over the same spot, and the rod should be read again with the same instrument on shore. The difference between the two readings, corrected for tidal changes, will be a measure of the combined effect of settlement and squat at the location of the acoustic units. Several such tests should be made and a mean of the results used.

*Second method:* Select an area which satisfies the requirements as to depth and bottom and anchor a marker buoy with a short scope. With the vessel stopped alongside the marker buoy the depth of water should be measured accurately with an echo-sounding instrument. Then the vessel should run past the marker buoy at normal sounding speed, taking another accurate echo sounding when in the same position relative to the buoy. Provision must be made for a record of the tidal change during the test. The difference between the echo soundings underway and stopped, corrected for change in tide, will be the combined amount of settlement and squat. The test should be repeated several times and the average value determined.

## 554. Adjustment of Index

All echo-sounding instruments used by the Coast and Geodetic Survey are provided with facilities for adjusting the index. Some instruments, such as the 312 Fathometer and the Veslekari, have one adjustment for the time of keying and another adjustment for the position of the index on the dial, which two adjustments are made independently. Other instruments are constructed so that the position of the index registered on the dial is governed by the position of keying, and to these only one adjustment is necessary.

With the draft, instrumental error, and settlement and squat, determined, the index of the echo-sounding instrument should be adjusted for the algebraic sum of these, by the methods described under the following headings for each type of instrument. For transceivers and separate transmitting and receiving units that are electrically coupled, the transmitted signal should register on the dial at a depth equal to the algebraic sum of the corrections. For other instruments such as the 312 Fathometer, the registration should be at a depth equal to the algebraic sum of the corrections *plus* one-half the distance of separation (see **556**). A notation shall be made in the Sounding Record each time the index of an echo-sounding instrument is readjusted.

### *5541. Dorsey Fathometer No. 1*

The index of the Dorsey Fathometer No. 1 is adjusted by means of a knurled knob centrally located on top of the indicator cabinet. A lock nut at the base of the knob must be loosened before an adjustment can be made, and after the adjustment the lock nut must be tightened. If it is not tightened firmly, the index may shift during operation. The fathometer attendant should be instructed to check the index adjustment at frequent intervals by observing the registration of the transmitted signal

and to notify the officer-in-charge if there is any appreciable change, so that an appropriate entry may be made in the Record.

### *5542. Dorsey Fathometer No. 3*

The Dorsey Fathometer No. 3 is designed for sounding in any depth of water and has three separate dials for use in different depths; and two of these are provided with circuits such that signals are transmitted only on alternate revolutions of the index. This design requires five separate photoelectric tubes and exciter lamps which are connected with separate keying circuits in which the lag may be slightly different, making the instrumental error different for each circuit. These five circuits are controlled by the depth-selector and starting-frequency switches and each is provided with a separate adjustment. These adjustments are inside the indicator cabinet, and their

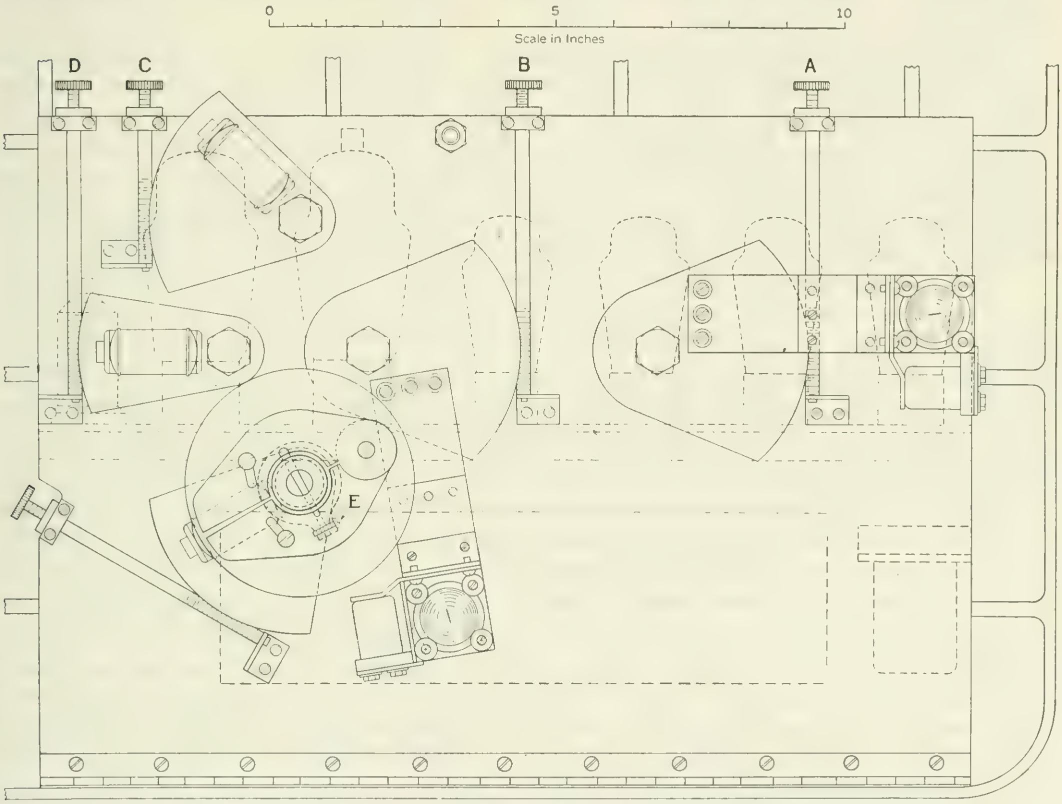


FIGURE 111.—Location of the index adjustments, Dorsey Fathometer No. 3.

positions are shown in figure 111. The identity of these adjustments with their corresponding circuits is as follows:

Knob *A* controls the position of the index of the 20-fathom dial.
Knob *B* controls the position of the index of the 20-fathom dial when alternate signals are deleted.
Knob *C* controls the position of the index of the 100-fathom dial.
Knob *D* controls the position of the index of the 100-fathom dial when alternate signals are deleted
Clamping screw *E* must be loosened to adjust the index of the 1,000-fathom dial.

The 1,000-fathom dial has a built-in adjustment, but it is provided with insufficient movement, so adjustment must be made by loosening the screw *E* in the clamp that engages the collar which is pinned to the shaft and turning the entire assembly to adjust the index.

Control knobs *A* to *D* are provided with lock nuts that serve to hold the index in adjustment and these have to be loosened before adjustment and retightened afterwards.

When making adjustments with knobs *C* and *D*, the photoelectric tubes must be kept within the illumination of the exciter lamps. If the proper index adjustment cannot be so made, proceed as follows: Turn the adjusting knob until the photoelectric tube is in the center of the illuminated area. Loosen the screw that clamps the shutter disk to the collar keyed to the shaft, and turn the disk until the neon tube flashes at the desired point on the depth scale. The adjusting knob can then be used for the final index adjustment.

Caution must be observed when sounding with this instrument to ensure that the correct starting-frequency and depth-selector switch combinations are used. Failure to use the correct combination of these switches will result in erroneous soundings. The correct combination is determined at the time of adjustment of the instrument and normally should be as follows: The depth-selector switch positions 1, 2, 3, and 4 must be used only with starting-frequency switch position 4, and depth-selector switch position 5 only with position 5 of the starting-frequency switch.

The index adjustment of the Dorsey Fathometer No. 3 may be made by either of two methods. *Method 1* should be used wherever practicable and particularly for surveys in regions of regular bottom such as are quite often found on the Atlantic and Gulf Coasts. *Method 2* may be substituted where *method 1* is impracticable, especially for surveys in regions of irregular bottom such as are generally found on the West Coast and in Alaska waters. In both methods the index of the 20-fathom scale is first adjusted to register the algebraic sum of the instrumental error, draft, settlement and squat by means of adjusting knob *A* in figure 111. The depth-selector switch must be on position 1 and the starting-frequency switch on position 4 while making this adjustment.

Then in *method 1*, the indices are adjusted until the depths registered on one scale agree with those registered on another as outlined below. But in *method 2*, the indices are merely adjusted to corresponding values, without reference to the depths.

*Method 1:* After the index of the 20-fathom scale has been adjusted, the other circuits are adjusted by a comparison of soundings. With the ship stopped in appropriate depths, where the bottom is smooth and level, the instrument may be switched from one dial setting to another by means of the depth-selector switch and the depths registered made to agree by use of the appropriate adjustment knob. Table 19 outlines this method of adjustment.

For example, if it is desired to adjust the index of the 100-fathom scale, the depth-selector switch should be set on position 3 and the starting-frequency switch on position 4. Using adjusting knob *C*, in figure 111, the depth registered on the 20-fathom dial should be adjusted to agree with the depth registered on the same dial when the depth-selector switch is turned to position 1, with the starting-frequency switch still on position 4. This adjustment should be made in a depth of water between 30 and 50 fathoms. In making this adjustment it is essential, as stated previously, that the photoelectric tubes remain fully in the beam of light.

*Method 2:* After the index of the 20-fathom scale has been adjusted, with the starting-frequency switch still on position 4, the indices for positions 2, 3, and 4 of the depth-selector switch are adjusted by means of adjusting knobs *B*, *C*, and *D*, in figure 111, to agree with the index for position 1 of the depth-selector switch.

TABLE 19.—*Index adjustments of Dorsey Fathometer No. 3.*

| Soundings read on— | Switches as follows | | Use adjustment (see fig. 111) | Adjust | Switches as follows | | Adjustments made in depths |
|---|---|---|---|---|---|---|---|
| | Depth-selector | Starting frequency | | | Depth-selector | Starting frequency | |
| | | | | | | | *Fathoms* |
| 20-fathom scale | 1 | 4 | A | Index for instrumental error, draft, settlement and squat. | 1 | 4 | ---------- |
| 20-fathom scale with cutout. | 2 | 4 | B | To sounding on 20-fathom scale. | 1 | 4 | 25 to 40 |
| 100-fathom scale | 3 | 4 | C | do | 1 | 4 | 30 to 50 |
| 100-fathom scale with cutout. | 4 | 4 | D | do | 1 | 4 | 30 to 50 |
| 1,000-fathom scale | 5 | 5 | E | To sounding on 100-fathom scale. | 3 | 4 | 100 to 200 |

For the 1,000-fathom index adjustment, both the starting-frequency and the depth-selector switches must be on position 5. By means of a temporary electric connection, a small amount of energy from the 525-cycle oscillator should be introduced into the input of the sonic echo amplifier—the amplifier used by the 312 Fathometer system. Then the gain of the amplifier should be lowered until only the transmitted signal caused by this coupling will be registered. Then the 1,000-fathom scale index is adjusted to the same value to which the other indexes were adjusted.

### *5543. 312 Fathometer*

The 312 Fathometer is provided with two adjustments by which the position of the index may be altered. One of these adjustments is on the back of the index disk inside the indicator cabinet. It is known as the draft adjustment. By means of it the position of the slit, through which the flash of the neon tube is seen, may be changed relative to the index disk on which it is located. The draft should be compensated for by this adjustment. The slit is in a movable segment of the disk. The wing nut securing this segment must first be loosened so the segment can be moved by hand to the desired setting as indicated by an engraved scale on the back of the index disk. Then the wing nut should be retightened.

The other adjustment is to vary the time of the transmitted signal with reference to the zero of the dial scale. By it the algebraic sum of the instrumental error and settlement and squat should be compensated for. This adjustment is made by varying the position of the dog which closes the electric contact. The dog is secured to the disk by two set screws, which are loosened so the dog may be moved around the disk to transmit the signal at the correct time with reference to the zero of the dial scale. The set screws should then be retightened.

For proper operation on the 100-fathom scale the contactor that operates the oscillator should be held closed for a period of time equivalent to 1 to 3 fathoms, depending on the installation. The contact surface of the dog is designed to accomplish this and it is also provided with a beveled surface to allow for adjustment. The distance between the contact points may be varied by loosening the nut under the brush of the contactor assembly and varying the adjustable stop which is a round disk having two flattened segments on opposite sides.

The angular rotation through which the contactors remain closed may be found by first placing the gears in neutral so the disk can be turned by hand. The disk is then turned slowly clockwise until the oscillator sounds and the red light flashes. The position of the left edge of the slit relative to the depth scale should be accurately noted when the red light flashes. Next, the disk is turned slowly counterclockwise until the oscillator sounds and the red light flashes. Again the position of the left edge of the slit relative to the depth scale should be accurately noted. The difference between these two scale readings will be a measure of the length of signal.

There is no adjustment of the index slit for the 600-fathom scale, such as is described above for the 100-fathom scale. Neither is there any independent adjustment of the dog for the 600-fathom scale, although a longer signal, equivalent to about 40 fathoms, is transmitted. Any adjustment of the dog for the 100-fathom scale also affects the transmitted signal on the 600-fathom scale. So all depths read on this scale must be corrected arithmetically. To determine the amount of the correction, a comparison of soundings read on this scale should be made with soundings read on the 100-fathom scale in a manner similar to that described in **5542** for the Dorsey Fathometer No. 3. The comparison should be made in depths of about 200 fathoms where the bottom is level and smooth. Each determination should consist of at least six comparisons and a number of determinations should be distributed throughout the time the deep scale is used. The average difference between the soundings as read on the two scales shall be applied arithmetically to all soundings read from the 600-fathom scale. The results of each such determination shall be recorded in the Sounding Record.

### *5544. Hughes Veslekari*

The Veslekari sounding instrument is usually operated simultaneously with the Dorsey Fathometer No. 3, and it should be adjusted to agree with the Dorsey Fathometer after adjustment of the latter in accordance with **5542**. During periods in which the Veslekari is being used, a simultaneous echo-sounding leadline comparison as described in **5521**, shall be made at least once a week, and in addition, at least three daily depth comparisons shall be made between the two instruments. The vessel need not be stopped for the latter, but the soundings should be reliable and preferably in depths less than 100 fathoms and over smooth level bottom. At a "mark" at the selected instant the sounding on the Dorsey Fathometer should be accurately read and simultaneously a mark should be made on the fathogram of the Veslekari by pressing the fix button. The depth registered on the Dorsey Fathometer should be entered on the fathogram and identified as such.

Before all comparisons the motor speed of the Veslekari should be verified in accordance with **5555**.

For the weekly comparison, or if the Veslekari is used on a ship which does not have a Dorsey Fathometer No. 3, the procedure should be as follows: With the motor speed in adjustment (see **5555**) a simultaneous echo-sounding leadline comparison should be made in a depth of 15 to 30 fathoms in accordance with **5521**. The phasing dial should be set on zero position and the depth scale should be adjusted so that its zero is at the left edge of the reference line recorded on the edge of the fathogram. The instrument should then be adjusted so that the depth recorded on the fathogram, after correction for the velocity of sound and settlement and squat, will equal the measured depth. The adjustment is made by stopping the instrument and then loosening the nut that holds the keying cam, thus allowing the cam to be turned manually in the

desired direction to make the recorded depths read the desired values. This nut should then be retightened and the instrument restarted, and another comparison made. This operation should be repeated until the fathogram depths have the desired relation to the measured depth.

An instrumental comparison with the Dorsey Fathometer can be substituted for the leadline comparison. The phasing dial of the Veslekari should be set on zero position and the depth-selector and starting-frequency switches of the Dorsey Fathometer on positions 1 and 4 respectively. The comparison should be made from the vessel stopped in a calm sea over smooth level bottom in a depth between 20 and 40 fathoms. If the depths registered on the two instruments do not agree within 0.3 fathom the Veslekari should be adjusted to agree with the Dorsey Fathometer. This adjustment is made as described above.

### *5545. 808 Fathometer*

The index of the 808 Fathometer is adjusted by means of a knurled hand screw, marked "zero adjustment," on the hinged door of the cabinet. The hand screw serves as a vernier adjustment to move the phasing dial by small amounts, and consequently to change the time of the transmitted signal slightly with reference to the printed scale of the fathogram. When the hand screw is turned so that the phasing dial moves clockwise the scale value of the index is increased, and decreased when it is moved counterclockwise.

This instrument should be adjusted for instrumental error, draft, and settlement and squat, by suspending a bar at a known depth (5 or 6 feet) below the bottom of the fish and turning the hand screw until the recorded sounding, when corrected for settlement and squat, equals the depth of the bar below the surface of the water. (See **557**.) The adjustment must be made with the phasing dial set on position **A** and the instrument recording in feet. The gain control should be set at the value normally used during surveying (between 7 and 10) and the correct motor speed must be maintained, as indicated by the reed tachometer (**5165***c*). After the index has once been adjusted by bar check, it shall not be readjusted until another bar check is taken, even though the recorded position of the transmitted signal may change.

The 808 Fathometer may be operated to record depths either in feet or fathoms and the times when the different units are to be used are specified in **3112**. The change from feet to fathoms is accomplished by a control which alters the speed of operation of the instrument in the ratio of 6 to 1, but the recorded position of the transmitted signal is *not* changed by this same ratio, as it should be for correct soundings. The closing of the contacts, which produces the transmitted signal, occurs at the same angular position of revolution with respect to the fathogram, being unaffected by the change in speed of operation. Except for other electric or mechanical imperfections, the following is an example of the error introduced. If the index has been adjusted so that the transmitted signal records at 2 feet, and the speed of operation is changed to the fathom scale, the transmitted signal will still record on the second division line, but this will now be equivalent to 2 fathoms, thus introducing an error of 10 feet in the recorded soundings.

For recorded soundings all in feet, or part in feet and part in fathoms, the instrument shall be adjusted with the instrument operating in feet, so that the recorded position of the transmitted signal (in feet) is correct. And *no change* shall be made in the adjustment for soundings recorded in fathoms.

When it is expected that soundings in both feet and fathoms will be recorded between bar checks the following procedure shall be followed: After the adjustment has been made with the instrument operating for soundings in feet, without moving the bar, the speed should be changed to soundings in fathoms and a record made of the transmitted signal. The difference between the latter and the former shall then be subtracted arithmetically, or graphically, from all soundings recorded in fathoms. This amount shall be noted on the fathogram as "Subtract____fms. from soundings in fathoms."

When soundings in fathoms only are to be recorded, the original adjustment may be made at the fathom speed, so that the recorded position of the transmitted signal is correct when scaled in fathoms.

## 555. Motor Speed

The depth scales of all echo-sounding instruments are calibrated for a selected velocity of sound in sea water. For instruments used by the Coast and Geodetic Survey this calibration velocity is generally 820 fathoms per second. The speed of the electric motor used to operate the instrument is related to the selected calibration velocity and the depth scales of the instrument. For correct results this speed must remain constant at the correct value. Any variation in motor speed will cause a proportional error in the registered soundings. In order to keep such an error at a minimum it is essential that the speed-governing or speed-indicating device be checked periodically.

### *5551. Verification of Tuning-Fork Frequency*

The indicator motor speed of the Dorsey Fathometer Nos. 1 and 3 is controlled by a tuning fork whose frequency is essentially constant. However, the frequency of the tuning fork must be verified at least once each year and if it has changed it should be corrected. It should be verified by one of the two following methods:

*Method 1:* This method is used by vessels operating within the range of the radio station thar transmits calibration signals. The signals are transmitted at the exact rate of 20.5 short pulses pet second, the rate being accurately controlled. To verify the frequency of the tuning fork, the radio signals are applied to the Fathometer so as to flash the 20-fathom dial indicator neon tube, as follows:

(*a*) Disconnect the output of the echo amplifier from the grid circuit of the type 885 gas discharge tubes that flash the indicator neon tubes, and connect the output of the radio receiver to this grid circuit. If the output impedance of the radio receiver is low it may be necessary to use a step-up transformer between the radio receiver and the grid circuit of the type 885 tubes. There must be a condenser (about 0.1 microfarad) in series with the lead going to the grids of the type 885 tubes, to prevent shorting their bias voltage to ground. In the case of the Dorsey Fathometer No. 3, the lead going to the indicator, numbered 25 on the terminal strip in the echo-amplifier cabinet, should be disconnected from the terminal and connected to the output of the radio receiver.

(*b*) Run the Fathometer at least 15 minutes before calibration. For the Dorsey Fathometer No. 3 the depth-selector switch should be on position 1 and the starting-frequency switch on position 4. Remove the type 59 oscillator tubes from the power supply.

(*c*) The radio calibration signals will produce flashes similar to echoes on the 20-fathom dial. If the tuning fork is vibrating at the correct frequency (1025 cycles per second) the flashes will appear stationary at some one point on the dial, but if it is off frequency they will move around the dial, in a counterclockwise direction if the frequency is low and in a clockwise direction if it is high. If the flashes make more than one revolution around the dial in 2 minutes, the frequency of the fork should be adjusted (see **5552**).

*Method 2:* This method should be used to verify the tuning-fork frequency of a Dorsey Fathometer No. 3, when beyond the range of the radio calibration signals. A break-circuit chronometer is employed in such a way that a flash is produced once each second on the dial of the Fathometer. The direction and speed at which these flashes move around the dial will be a measure of the tuning-fork frequency.

The procedure is as follows:

(a) A 1-second break-circuit chronometer, such as is used in Radio Acoustic Ranging, must be used. Connect the contact circuit of the chronometer and a resistance-condenser combination to the points in the indicator as indicated in figure 112. The values of the resistance and capacitance of the combination are not critical. The connection marked $X$ in the figure is made by removing any one of the three left-hand type 885 gas discharge tubes which are mounted on the back hinged panel of the indicator, inserting the end of the wire in the grid hole of the tube socket, and replacing the tube, thus holding the wire in place. Connection $Y$ is made to the variable tap nearest ground on the bias potential divider. The voltage of this tap is about minus 50 volts. If the circuit operation is not satisfactory, connection $Y$ may be moved by a slight amount on the potential divider.

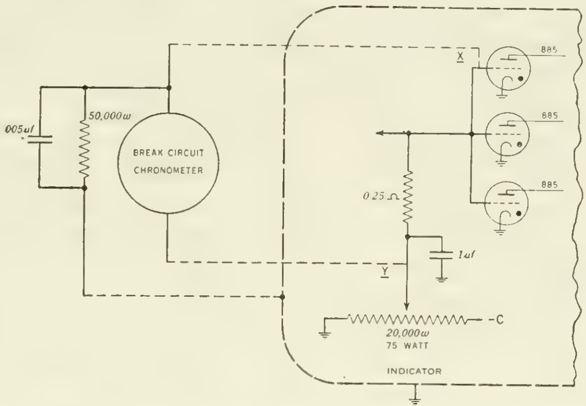


FIGURE 112.—Circuit for verification of tuning-fork frequency by chronometer.

This divider is located in the left end of the indicator. Make certain that the potential divider is that of the bias supply and not that of the high-voltage supply.

(b) Run the Fathometer 15 minutes before calibration. Set the depth-selector switch on position 1 and the starting-frequency switch on position 4.

(c) Count the flashes on the 20-fathom dial as a measure of time. If the flashes precess more than 2 fathoms in 12 seconds the tuning fork should be adjusted as described in **5552.** Clockwise precession of the flashes indicates that the fork frequency is too high, and counterclockwise precession indicates that the fork frequency is too low. The flashes will appear alternately 180° apart on the dial, once each second. Every flash must be counted in making these measurements, not just those at one position on the dial.

## *5552. Frequency Adjustment of the Tuning Fork*

The frequency of the tuning fork in the Dorsey Fathometers can be increased or decreased by filing certain of its parts. If tests indicate that the tuning-fork frequency is too low, it should be increased by filing the vertical edges of the ends of the fork tines. The fork must be removed before filing to prevent filings from getting on the head receiver magnet or on the driving-coil pole pieces. A fine file should be used. By beveling the two vertical edges of each tine, one can judge by eye when equal amounts have been taken off each edge. When filing the fork the first time, only a small amount should be filed off before a second test, or until the effect that a given amount of filing on the frequency has been determined. It may be necessary to remove and file, and replace and test the fork several times before it has the correct frequency. When replacing the fork in its mounting, paper shims should be inserted between the tines of the fork and the pole pieces of the pickup and driving magnets so as to locate the fork properly relative to these poles pieces.

If the frequency of the fork is too high, it should be lowered by filing with a fine half-round file in the crotch of the fork. The fork need not be removed for this but all the filings should be collected after the operation. File equal amounts from the crotch on each side of the centerline. Count the number of file strokes so that equal amounts will be removed from each side. Repeat the filing operation until the fork is properly tuned.

### *5553. Verification and Adjustment of 312 Fathometer*

The motor speed of the 312 Fathometer is indicated by a reed tachometer (see **5234**). The tachometer shall be removed from the instrument and forwarded once each year to the Washington Office for calibration. During the field season the calibration of the tachometer shall be verified at least once each month by the following method and the result recorded in the Sounding Records.

The transmitted signals of the 312 Fathometer will record on the chronograph (see **673**), when the latter is operated as for Radio Acoustic Ranging. The Fathometer should be run for a warm-up period of about 30 minutes before making a test. If the calibration of the Fathometer is for a velocity of sound of 820 fathoms per second, 4.1 signals per second should be transmitted at fast speed; and if the calibration is for a velocity of sound of 800 fathoms per second, exactly 4 signals per second should be transmitted. For the test the chronograph should be run at least 1 minute, the 312 Fathometer being operated at fast speed, with its speed continuously adjusted to give maximum vibration of the middle reed of the tachometer.

If the tachometer is found to be in error, a reed other than the middle one may indicate the correct velocity. Test other reeds at maximum amplitude until one is found which most nearly indicates the correct velocity and operate the Fathometer on this basis until the tachometer can be corrected. Measure the speed of index revolution with this reed vibrating at maximum amplitude, and calculate the corresponding velocity of sound. Use this as the calibration velocity of the instrument in computing the correction factors (see **5613**) for all soundings taken under these conditions.

Where a chronograph is not available, the middle reed of the tachometer may be checked, with a fair degree of accuracy, by timing a certain number of revolutions of the slow speed dial with a stop watch. It should be noted that the tachometer is equally effective at the slow and fast speeds of the Fathometer. The accuracy of the stop watch should be verified by comparison with a chronometer of known rate. The Fathometer should be run for at least a half-hour before testing the frequency of the tachometer. The Fathometer should be operated at slow speed using the automatic cutout so that a signal will be transmitted every alternate revolution of the index disk. The gain of the amplifier should be reduced so that the echo cannot be heard. For the test the echo-listening device should be used to listen to the transmitted signals. The stop watch should be started at the beginning of some signal and, calling this zero, 204 signals should be counted and the watch stopped at the beginning of the 205th signal, for an instrument calibrated for a velocity of sound of 820 fathoms per second. Throughout this test the middle reed of the tachometer must be kept vibrating at maximum amplitude. If the frequency of the middle reed is correct, the corrected stop watch reading should be exactly 10 minutes.

If the corrected stop watch time differs from 10 minutes, the frequency of the reed is incorrect and the

$$\text{Correction (in percent)} = \frac{T-600}{T}$$

and

$$V_1 = V\frac{600}{T}$$

where $T$ equals the actual time (in seconds) for the 205 transmitted signals, $V$ equals the velocity of sound for which the instrument is calibrated, and $V_1$ equals the velocity of sound for which the instrument is actually operating during the test.

For instruments calibrated for a velocity of sound of 800 fathoms per second the procedure is the same, except that 200 transmitted signals should be counted instead of 205.

### *5554. Verification and Adjustment of 808 Fathometer*

The reed tachometer of the 808 Fathometer is identical with that of the 312 Fathometer. It also shall be removed from the instrument once a year and forwarded to the Washington Office for calibration. And during the field season its frequency shall be verified at least once a month and the results recorded in the Sounding Records. The purpose of the monthly check is not to determine the exact frequency of the middle reed but to discover if a change of frequency has occurred.

At correct motor speed, the travel speed of the fathogram under the stylus is exactly 2 inches per minute, so an approximate verification may be made by measuring the length of paper that moves under the stylus in a given time while the middle reed is vibrating at maximum amplitude. The instrument should be operated for a half-hour at slow speed, after which it should be changed to fast speed for the test. The motor speed should be adjusted and maintained during the test so that the middle reed vibrates continuously at maximum amplitude. A stop watch, whose rate has been verified, is started simultaneously with the pressing of the fix-marker button. At the end of exactly 4 minutes by the stop watch the fix-marker button is again pressed. If the frequency of the middle reed is correct, the measured distance between the two fix marks should be exactly 8 inches. The measurement should be made between the right edges of the marks at the center of the fathogram and by means of a graduated scale—not by the printed scale on the fathogram. A difference of 0.1 inch from 8 inches will indicate a deviation of 1¼ percent from calibrated frequency. If there is any question as to the validity of the result, the test should be repeated several times. Should these tests indicate a change in the frequency of the reed, follow the instructions in **5553** for the 312 Fathometer until the tachometer can be readjusted. (See also **5233** and **5238**(*q*).)

### *5555. Verification and Adjustment of Veslekari*

A check of the Veslekari motor speed should be made before each day's operations, and this fact should be noted on the fathogram. The motor speed of the Veslekari echo-sounding instrument is adjusted by the manufacturer for a calibration velocity of sound of 800 fathoms per second. A velocity of sound of 820 fathoms per second is more nearly average for the waters surveyed by the Coast and Geodetic Survey, and since most of the other instruments used are so calibrated and adjusted, the motor speed of the Veslekari should be altered to correspond to a calibration velocity of 820 fathoms

per second. Instruments of this type are now used simultaneously with, and to supplement, the Dorsey Fathometer No. 3. Since the motor of the latter is tuning-fork controlled, its speed is quite accurate and may be used as a speed standard for the Veslekari instrument.

The Veslekari may be adjusted to a calibration velocity of 820 fathoms per second by comparison with the Dorsey No. 3. The two instruments should be warmed up for a half-hour, after which the gain of the echo amplifier of the Veslekari is increased until the transmitted signal of the Dorsey Fathometer records on the fathogram of the Veslekari. The Dorsey Fathometer should have the depth-selector switch on position 3 and the starting-frequency switch on position 4.

Because the Dorsey Fathometer is transmitting more than four signals for each stylus cycle of the Veslekari there will always be one and sometimes two transmitted signals of the Dorsey Fathometer recorded for each of these cycles. These may occur at any position relative to the index of the Veslekari.

If the speeds of the two motors were synchronized for the same velocity of sound, the Dorsey signals would record in a vertical line on the fathogram. If the two speeds differ, the successive signals of the Dorsey instrument are recorded at advanced or retarded positions for each cycle of the Veslekari, resulting in a line of recorded signals that crosses the fathogram at an angle.

For perfect instrumental speed, the governor of the Veslekari motor should be adjusted so that the Dorsey signals record in a nearly vertical line, but such an adjustment is almost impossible to effect and to maintain. The governor adjustment may be considered satisfactory if the time from the first recorded Dorsey signal at one edge of the fathogram to the last recorded signal (of the same cycle) at the other edge is more than 3½ minutes.

Where the Veslekari is on a ship where there is no Dorsey Fathometer No. 3 with which to compare its motor speed, the speed may be verified by timing the revolutions of the phasing-switch brush. For a velocity of sound of 820 fathoms per second, the phasing-switch brush of the Veslekari should rotate at 0.3417 r.p.s. The instrument should be run for a half-hour before starting the test. The front of the recorder cabinet should be open while the test is made. A reference mark should be made or noted on the stationary part of the phasing switch, which is directly behind the phasing dial when the front of the cabinet is closed. As the phasing-switch brush passes the reference point, start a stop watch and count 41 revolutions of the brush, and stop the stop watch at the end of the 41st revolution. If the motor speed is correct the measured time should be 120 seconds.

### 556. SEPARATION EFFECT

For an echo-sounding instrument with separate transmitting and receiving units, the physical separation of the units must be taken into account. This separation has two effects on echo soundings, (*a*) to make the registered depth greater than the actual depth, and (*b*) to make the transmitted signal register later than it would if there were no separation between units, unless the units are electrically coupled.

The first of these two effects is caused by the inclination of the sound path (*AC* and *CB* in fig. 113) due to the separation of the acoustic units. This introduces an error that increases with an increase in the distance between the acoustic units but decreases with an increase in the depth of water. It is appreciable only in comparatively shoal water. Where the depth of water is five times the distance of separation between acoustic units, the true depth is 99.5 percent of the registered depth. Where

the ratio of the depth of water to the distance between acoustic units is greater than 5 to 1, this effect may be neglected—but where the ratio is less it must be taken into account by compensation or correction. Soundings may be corrected by use of the formula:

$$E=d+\sqrt{(D-d)^2-\frac{S^2}{4}}$$

where $E$=echo sounding corrected for separation effect; $d$=mean draft of the acoustic units; $D$=depth registered on the echo-sounding instrument; and $S$=horizontal distance between the centers of the acoustic units. All values must be expressed in the same units.

Some echo-sounding instruments, for example the 312 Fathometer, compensate for this separation error by having the shoal end of the scale on which the soundings are registered, graduated to compensate for an assumed distance between the acoustic units. For the 312 Fathometer, this distance is 24 feet, and the instructions for installation specify that the units shall be installed this distance apart. If acoustic units separated by any other distance are used with the 312 Fathometer, the registered soundings must be corrected for the error introduced by the difference between the actual distance of separation and 24 feet.

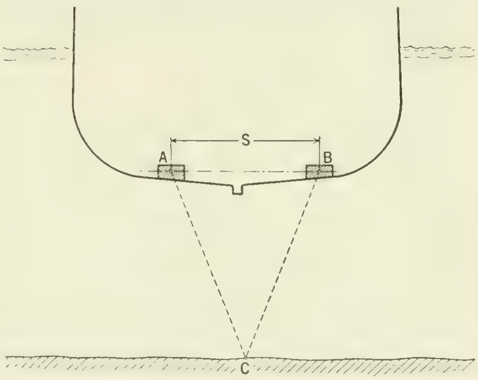

FIGURE 113.—Separate acoustic units.

This separation effect does not exist for instruments using a transceiver, such as the Dorsey Fathometers No. 1 and No. 3. It may be neglected entirely for instruments with only a small separation between the acoustic units, such as the 808 Fathometer, and the Hughes *MS* 12 *D*. And it may be disregarded in all cases where the soundings are greater than five times the distance between the acoustic units.

The second effect of separation is the lag in registration of the transmitted signal. This is caused by the time required for the sound to travel from the transmitting unit to the receiving unit. The effect of this may be better understood by comparing an instrument using a transceiver with an instrument which has a separation between its transmitting and receiving units. In the transceiver the same unit is used for transmitting and receiving, and it is obvious that there can be no lag between the time of emission and the time of reception of the transmitted signal. By comparison, where there is a separation, the sound of the transmitted signal must travel through the water, or steel hull of the vessel, to the receiving unit, registering late by an amount approximately equal to one-half of the distance $S$ (fig. 113) between the units, in terms of the depth scale. In the 312 Fathometer, for example, if the units are installed 24 feet apart, disregarding any other adjustments, the transmitted signal should register on the depth scale 2 fathoms beyond the point where the index was when the signal was transmitted.

This lag in the registration of the transmitted signal does not, of itself, introduce any error in the registered depths read independently. However, it must be considered when making index adjustments to certain instruments and also when scaling fathograms. Where there is a separation between the transmitting and the receiving unit.

the index must not be used as a reference for making compensatory adjustments, with the instrument in operation. The method described in **5543** for adjusting the index of the 312 Fathometer avoids any effect of the separation error, since the readings are made while the index disk is turned manually and very slowly. In making index adjustments, the introduction of an error due to separation must be avoided in the Veslekari, the 312 Fathometer, and in the Dorsey Fathometer No. 3 should it be adjusted using the sonic system only. For the proper methods of adjusting these instruments, see **5544**, **5543**, and **5542**.

In using a graphic-recording instrument that utilizes a transceiver, or separate acoustic units so close together that the separation is negligible, the depth measured below the units is recorded on the fathogram by the difference in the recorded positions of the transmitted signal and received echo. This is not so if there is an appreciable separation between the acoustic units, because the transmitted signal will be recorded too late by one-half the distance between the units in terms of the depth scale, and this fact must be taken into consideration in scaling the fathograms.

## 557. Bar Check

The *bar check* is a method whereby the accuracy of an echo-sounding instrument may be verified. It consists of lowering a flat bar horizontally below the acoustic units to serve as a reflector, thus forming a nearly perfect artificial bottom at an accurately known depth, with which the registered depth can be compared. By using the bar check, the index of an echo-sounding instrument operated at a constant velocity may be adjusted to compensate for the draft of the acoustic units and the instrumental error without knowledge of their amounts (**5545**); and under certain conditions, for a velocity of sound differing from the calibration velocity of the instrument (**5617**). At the time of the bar check the index should be adjusted for settlement and squat if appreciable and known (see **553**).

Reliable bar checks can be made only in a calm sea and are usually limited to a depth of about 15 fathoms. With difficulty bar checks can sometimes be made to greater depths but the results are likely to be unreliable. In a moderate or choppy sea the maximum bar-check depth may be as little as 2 fathoms, owing principally to the difficulty of keeping the bar horizontal, and vertically below the acoustic units. The minimum bar depth at which echoes can be recorded usually depends on the echo-sounding apparatus.

Because bar checks are most advantageously used in connection with shoal soundings, the method is principally used to verify and adjust shoal-water semiportable echo-sounding instruments, such as the 808 Fathometer and the Hughes *MS* 12 *D*.

### *5571. Bar Check Apparatus*

The bar, used as a reflecting surface, is a rectangle supported at its ends by lines in such a way that it is held in a horizontal position when submerged. The bar may be of metal or wood, metal being preferred because it will sink of its own weight. The bar must be rigid enough so that it does not sag and it must be rigged so that it can be suspended in a horizontal position, at a known depth, and be kept vertically under the acoustic units. The bar should be as long and wide and heavy as can be conveniently handled, for then there will be less difficulty in keeping it in position below the acoustic units. For the 808 Fathometer the *minimum* size of bar which should be used is about 3 feet long, 9 inches wide, and ¼ inch thick if iron and ¾ inch thick if wood. If numerous

holes are bored in the bar to permit the free flow of water, it can be kept in position more easily. At each end of the bar there should be a wire or rope yoke in the form of an inverted V to which the supporting lines are attached. The supporting lines should be wire or have wire cores, like the material used for leadlines. The lines should be marked and their lengths should be verified in accordance with the instructions for the leadline (**4621** and **4622**). Measurements are made from the upper surface of the bar.

If the bar is made of wood, a type suitable for submersion, such as cypress, should be used. The bar should be kept well painted, for waterlogged wood is inefficient as a reflector. Narrow metal strips should be fastened to the underside of the bar to prevent warping.

Two weights should be attached, one at each end, to the underside of the board to keep the supporting lines taut.

Under favorable conditions satisfactory reflections should be received from a bar 9 inches wide to a depth of 15 fathoms; but under unfavorable conditions and at greater depths, more distinct echoes will be received from a wider bar.

Air is an almost perfect reflector of sound in water. If any difficulty is experienced in receiving echoes from a bar in calm waters, construct a bar which incorporates a thin layer of air near its upper surface. A cellular rubber sheeting will serve for this purpose.

### *5572. Frequency of Bar Checks*

For echo sounding with an 808 Fathometer, or similar instrument, used in a launch, bar checks shall be made under the following conditions, and at the following frequencies:

(*a*) In protected waters where there is every reason to believe the results of the bar checks are dependable, and the range of depths sounded can be covered by the bar-check range, the index shall be adjusted by bar check, and bar checks shall be made on the descent and ascent of the bar at each 10 feet throughout the range of depths sounded—three times daily, at the beginning and end of the day's work and once near the middle of the day.

(*b*) Where most of the depths sounded are beyond the range of the bar check, other conditions being as in (*a*), the index shall be adjusted by bar check, and one check shall be made at the deepest depth at which a dependable result can be obtained, and one check shall be made at a depth in the overlap between phases—three times a day as in (*a*).

(*c*) In exposed waters, where dependable results cannot be obtained, the index shall be adjusted by bar check (preferably in a protected place)—at least twice, and preferably three times daily—but no other bar checks shall be made.

(*d*) In adjusting the index (see **5545**), *before* the start of the day's hydrography the index shall be adjusted to make the bar depth record correctly, but *after* any sounding the bar depth reading must be recorded on the fathogram *before* the index is adjusted as well as after it has been adjusted.

(*e*) Where the results of bar checks are to be used for correcting or compensating for the velocity of sound (see **5617**), not less than three complete bar checks per day shall be made, the bar check must cover at least 75 percent of the range of depths sounded, and the bar checks must be most accurate and dependable. (See also **5616*a*** and **5617**.)

## 56. CORRECTIONS TO ECHO SOUNDINGS

In addition to the corrections that are so nearly constant that they can be made by some instrumental adjustment, there are other corrections that vary with time, place, and depth to such an extent that instrumental compensation is usually not attempted. These latter are the correction for tide, the correction for a velocity of sound differing from the calibration velocity of the instrument, and the correction for slope.

The correction for tide is usually applied algebraically—it is always so made in the Coast and Geodetic Survey to soundings recorded in the Sounding Record, regardsles of the method of obtaining the soundings, and in accordance with **822**. In river

and harbor surveys, where the plane of reference is known in advance and communication can be maintained between the tide station and the survey party, the necessary corrections are sometimes applied as the soundings are taken, and there are echo-sounding instruments with an adjustment by which the correction for tide can be applied instrumentally (see **529**). Also, in the case of soundings recorded graphically, it is possible to apply the correction for tide mechanically or graphically at the time the depths are scaled (see **562**).

The correction for the variation in the velocity of sound is, perhaps, the most important correction to be made to echo soundings. In the Coast and Geodetic Survey all echo-sounding instruments are operated at an instrument speed selected to register soundings based on a chosen velocity of sound, known as the calibration velocity. Whenever the actual mean velocity of sound from surface to bottom differs from this calibration velocity, a correction must be applied. This correction is usually made by algebraic addition to soundings recorded in the Sounding Record, although it can be made by instrumental adjustment (see **5616**), assuming an advance knowledge of the velocity of sound, or it can be made mechanically or graphically to soundings scaled from fathograms (see **562**). The methods of deriving and applying corrections for the velocity of sound are described in **561**.

Echo soundings registered on some echo-sounding instruments do not represent vertical depths in areas of irregular submarine relief and, theoretically, so-called corrections for slope should be made. It is not practical to do this with any great precision in most cases, and there are other reasons why it should not be done. (See **563**.)

## 561. Velocity Corrections

In echo sounding the sound wave passes vertically downward through a column of water in which the velocity of sound differs at different depths, and since the true depth is a product of velocity and time, the average velocity from surface to bottom must be known for each sounding. The velocity of sound in sea water depends on the temperature, salinity, and pressure (see section **63**), and the velocity of sound used in echo sounding is usually calculated from these physical characteristics.

The hydrostatic pressure increases in direct proportion to depth, and the temperature and salinity of the water usually decrease with depth, but not necessarily proportionally. The result is that the velocity of sound, by which an echo sounding must be computed, is seldom uniform from surface to bottom. Hence, the average velocity of sound from surface to bottom will be different for echo soundings of different depths. Furthermore, due to regional and seasonal changes in the physical conditions, the average velocity from surface to bottom for the same depth changes from place to place and from time to time.

Because of the theoretically linear relationship which exists between the travel time required for an acoustic wave to travel between two points, and the distance between them, echo-sounding instruments may be calibrated in units of depth. Those used by the Coast and Geodetic Survey are driven by motors operated at a constant speed for a pre-selected velocity of sound, usually 820 fathoms per second (see **555**). This is known as the calibration velocity. Therefore, whenever the average velocity of sound from surface to bottom differs from the calibration velocity of the echo-sounding instrument, the registered depths must be corrected to what they would have been on an instrument calibrated for this actual velocity. This correction is known as the *velocity correction.*

To correct any sounding it is necessary to know the average velocity of sound from surface to bottom and the calibration velocity of the echo-sounding instrument. From these a factor may be derived by which to multiply a registered depth to find the correction to be added to or subtracted from it. This factor is found from the formula:

$$\frac{\text{Actual mean velocity} - \text{calibration velocity}}{\text{calibration velocity}} = \pm \text{factor}$$

Theoretically, for each sounding the velocity of sound should be known at every depth from surface to bottom in order to have a correct mean velocity. Practically, of course, it is necessary to use average velocities based on average conditions of temperature and salinity for certain periods of time and for certain areas. The extent of the area and the time through which average conditions may be assumed depend on the stability of the physical conditions during the period of the survey.

There are several methods by which a correction for velocity may be made. The universal one, which is applicable in any case, is the algebraic method outlined in **5611**, by which velocity corrections for soundings of various depths are derived algebraically, and are applied to the recorded soundings algebraically. Other methods of more limited application, which may be used in special circumstances, are described in **5616, 5617,** and **562**.

### *5611. Velocity Correction by Algebraic Method*

Since the temperature and salinity of the water vary irregularly with depth, and since it is necessary to determine a correction for velocity for the entire depth, the conditions at various depths must be considered and at some point in the computations averages must be derived applicable to the entire depth, or the corrections may be found by summation. The temperatures and salinities from surface to bottom may be averaged to find average conditions for the entire column of water, from which one velocity may be derived; or velocities from surface to bottom may be averaged to find an average velocity for the entire depth; or the column of water from surface to bottom may be considered layer by layer and a correction for each depth layer determined, the summation of which will give the correction applicable to a given depth. The last has been adopted by the Coast and Geodetic Survey as the most practicable means of deriving the corrections. It can be accomplished either numerically or graphically, the two methods being described in **5613** and **5615** respectively.

The various steps to be performed to determine velocity corrections by the algebraic method are as follows:

(1) After all of the serial temperatures and scattered temperature and salinity observations have been plotted on Form *B*-1528-5, in accordance with **6342**, a study must be made of the results to determine how these can be grouped best by area and by time to permit mean curves to be drawn. These mean regional temperature and salinity curves are made in accordance with **5612**, each being plotted on Form *B*-1528-5.

(2) After the mean regional temperature and salinity curves are available, a study of these must be made to select the depth layers for which the physical conditions must be considered. Layers must be selected of such thicknesses that the conditions at the midpoint may be considered applicable to the entire layer. Usually it will be found necessary to adopt layers of less thickness near the surface, but as the depth increases and the physical conditions change less relatively with depth, thicker layers may be adopted.

(3) The temperatures and salinities scaled from the mean regional curves for the midpoints of the adopted layers are then used to derive, numerically or graphically, the velocity correction for each

ayer and these are summed numerically or graphically to find the corrections for various depths, in accordance with **5613** or **5615**.

(4) The velocity corrections for the various depths are then plotted and a graph is drawn through them, from which the correction for any echo sounding may be scaled, as described in **5614**.

### *5612. Mean Regional Temperature and Salinity Curves*

It is desirable to correct registered soundings for the error due to velocity with as great an accuracy as practicable, but it is not considered practicable to utilize each serial temperature and each separate temperature and salinity observation individually for this purpose. For practical reasons it is necessary to derive curves representing the average conditions throughout a given area and through a given time period which will be close enough to reality so that no appreciable errors will be introduced from the use of the averages. At all events the over-all requirements of accuracy of depth measurements, as prescribed in **3111**, must be met, and the velocity corrections should be determined with an accuracy so that no sounding will be in error from this correction alone by more than one-half percent. (See **6313**.)

To fulfill these requirements a sufficient number of temperature and salinity measurements must be made in the project area. The frequency with which the observations should be made is considered in **6322** and **6332**. Previously acquired knowledge of the temperature and salinity conditions in nearby areas can sometimes be used as a guide as to the probable number of observations required. Lacking any previous knowledge of conditions in the area to be surveyed, the observations should be made with a greater frequency at the beginning of the project, and these will disclose the necessary frequency and distribution of observations needed for the remainder of the project.

After all of the serial temperatures and separate temperature and salinity observations for the season have been plotted on Form *B*-1528-5, a study must be made of the results to see how these may be grouped by areas and by time periods, for the purpose of preparing mean curves. The area and the time period for which a mean curve may be adopted will vary from an entire season's work to the area surveyed in one trip on the working ground. Past experience has shown that all of the serial temperatures of an entire season's hydrography on the Pacific Coast, in Alaska, or in the Hawaiian Islands may often be combined for the average curves for an entire season. It is a matter that must be left to the hydrographer's judgment, but it must be borne in mind that, to comply with the requirements, the average temperature from surface to bottom used to correct any sounding must be within 2° of the actual mean temperature (see **6313**).

A study of the serial temperatures may disclose that all of them can be combined into one mean curve, except those taken in one locality or during one period of time. When this is so, these latter serial temperatures should be segregated from the rest and used for the derivation of supplemental mean curves for that particular locality or time period.

Mean salinity curves are also required. As compared to temperature, however, the variation normally encountered in salinity has comparatively slight effect on velocity and, except in extreme cases, one mean salinity curve can be used throughout the entire season, even when a number of mean temperature curves are required.

After the areas and time periods have been decided on, mean representative curves are drawn. This may be done graphically or mathematically. In the former method, the curves to be averaged are plotted on Form *B*-1528-5 and by inspection the mean curve is drawn. This method will be found preferable in most cases, and it has the advantage of disclosing immediately any individual curve that varies excessively from the average, and which should be rejected or at least not be included in this group. Various colors should be used to differentiate between the different curves, black being used for the mean curves.

In the mathematical method, selected representative depths are chosen and the temperatures and salinities at these depths scaled from the separate serial temperature curves (see **5611** (1)). The arithmetic mean at each depth is then found and plotted on Form *B*-1528-5, and a smooth curve is drawn through the points; or the arithmetic means, if the depths have been chosen with this in mind, may be entered directly in columns *B* and *C* in the form on which the velocity correction computations are made (see table 20). This mathematical averaging of the temperatures and salinities eliminates the necessity for replotting all the serial temperature curves and the difficulty that may be experienced when a number of curves plot very close to one another.

For depths greater than 120 fathoms, each temperature curve shall be plotted in two parts, the shoaler part at the scale provided on Form *B*-1528-5, and the deeper part at a scale one-tenth of that used for the shoal section. These should be drawn and the separate parts identified in accordance with instructions in **6342**.

### *5613. Numerical Determination of Velocity Corrections*

Velocity corrections may be derived numerically or graphically, steps (1) and (2) below being the same in either case. For the purpose of illustration an example of velocity correction computations by the numerical method is given in table 20, with columns identified by the letters (*A*) to (*I*) for reference purposes only. This is the standard form which shall be used for all corrections derived by the numerical method. The graphic method of deriving velocity corrections is described in **5615**.

It must not be assumed that all depth layers, for the purpose of determining velocity corrections, need to be chosen as shown in this example, but from past experience 5-fathom layers in the upper hundred fathoms, 20-fathom layers in the second hundred fathoms, and 200-fathom layers in greater depths have usually been found satisfactory. Where the change in temperature is regular with respect to depth and not too great, thicker layers may give sufficient accuracy. On the contrary, for precise results in shoal water 5-foot intervals may even be required at times.

TABLE 20.—*Example of velocity correction computations*

[Computed for echo soundings taken with an instrument calibrated for a velocity of sound of 820 fathoms per second.]

| (A) Mid-depth of each layer | (B) Temperature | (C) Salinity | (D) Layer velocity | (E) Mean velocity | (F) Correction factor | (G) Layer correction | (H) Depth correction | (I) Applicable depth |
|---|---|---|---|---|---|---|---|---|
| *Fathoms* | °*C.* | ‰ | *Meters per second* | *Meters per second* | | *Fathoms* | *Fathoms* | *Fathoms* |
| 4. 5 | 19. 6 | 33. 6 | 1, 516. 1 | | +0. 0110 | +0. 0550 | +0. 06 | 7 |
| 9. 5 | 19. 2 | 33. 7 | 1, 515. 4 | | +0. 0105 | +0. 0525 | +0. 11 | 12 |
| 14. 5 | 18. 5 | 33. 8 | 1, 513. 7 | | +0. 0094 | +0. 0470 | +0. 15 | 17 |
| 19. 5 | 15. 9 | 33. 9 | 1, 506. 0 | | +0. 0043 | +0. 0215 | +0. 18 | 22 |
| 24. 5 | 10. 7 | 34. 0 | 1, 488. 8 | | −0. 0072 | −0. 0360 | +0. 14 | 27 |
| 29. 5 | 7. 7 | 34. 1 | 1, 477. 9 | | −0. 0145 | −0. 0725 | +0. 07 | 32 |
| 34. 5 | 8. 4 | 34. 3 | 1, 481. 0 | | −0. 0124 | −0. 0620 | +0. 01 | 37 |
| 39. 5 | 9. 3 | 34. 4 | 1, 484. 7 | | −0. 0099 | −0. 0495 | −0. 04 | 42 |
| 44. 5 | 10. 4 | 34. 6 | 1, 488. 9 | | −0. 0071 | −0. 0355 | −0. 08 | 47 |
| 49. 5 | 11. 5 | 34. 7 | 1, 493. 4 | | −0. 0041 | −0. 0205 | −0. 10 | 52 |
| 54. 5 | 12. 1 | 34. 9 | 1, 495. 9 | | −0. 0025 | −0. 0125 | −0. 11 | 57 |
| 59. 5 | 12. 4 | 35. 0 | 1, 497. 1 | | −0. 0017 | −0. 0085 | −0. 12 | 62 |
| 64. 5 | 12. 5 | 35. 2 | 1, 497. 8 | | −0. 0012 | −0. 0060 | −0. 13 | 67 |
| 69. 5 | 12. 5 | 35. 4 | 1, 498. 2 | | −0. 0009 | −0. 0045 | −0. 13 | 72 |
| 74. 5 | 12. 4 | 35. 6 | 1, 498. 3 | | −0. 0009 | −0. 0045 | −0. 14 | 77 |
| 79. 5 | 12. 3 | 35. 7 | 1, 498. 3 | | −0. 0009 | −0. 0045 | −0. 14 | 82 |
| 84. 5 | 12. 1 | 35. 8 | 1, 498. 0 | | −0. 0011 | −0. 0055 | −0. 15 | 87 |
| 89. 5 | 11. 9 | 35. 9 | 1, 497. 6 | | −0. 0013 | −0. 0065 | −0. 15 | 92 |
| 94. 5 | 11. 7 | 36. 0 | 1, 497. 1 | | −0. 0017 | −0. 0085 | −0. 16 | 97 |
| 98. 5 | 11. 4 | 36. 1 | 1, 496. 3 | | −0. 0022 | −0. 0066 | −0. 17 | 100 |
| 110 | 11. 1 | 36. 1 | 1, 495. 6 | | −0. 0027 | −0. 0540 | −0. 22 | 120 |
| 130 | 9. 5 | 36. 2 | 1, 490. 5 | | −0. 0061 | −0. 1220 | −0. 34 | 140 |
| 150 | 8. 5 | 36. 2 | 1, 487. 4 | | −0. 0081 | −0. 1620 | −0. 51 | 160 |
| 170 | 7. 8 | 36. 1 | 1, 485. 2 | | −0. 0096 | −0. 1920 | −0. 70 | 180 |
| 190 | 6. 7 | 36. 0 | 1, 481. 8 | | −0. 0119 | −0. 2380 | −0. 94 | 200 |
| 300 | 5. 4 | 34. 5 | 1, 478. 3 | | −0. 0142 | −2. 8400 | −3. 78 | 400 |
| 500 | 4. 2 | 35. 2 | 1, 480. 9 | | −0. 0125 | −2. 5000 | −6. 28 | 600 |
| 700 | 3. 9 | 35. 1 | 1, 486. 0 | | −0. 0091 | −1. 8200 | −8. 10 | 800 |
| 900 | 3. 7 | 35. 1 | 1, 491. 8 | | −0. 0052 | −1. 0400 | −9. 14 | 1, 000 |
| 1, 100 | 3. 5 | 35. 0 | 1, 497. 4 | | −0. 0015 | −0. 3000 | −9. 44 | 1, 200 |
| 1, 300 | 3. 3 | 35. 0 | 1, 503. 2 | | +0. 0024 | +0. 4800 | −8. 96 | 1, 400 |

The procedure, referring to table 20, is as follows:

(1) The transmitted sound originates at, and the echo returns to, an acoustic unit which is some distance below the surface of the water. For survey ships, for velocity correction purposes, this may be assumed to be 2 fathoms. (For auxiliary vessels and launches the acoustic units are at other depths, which should be used.) Starting then at 2 fathoms below the surface, divide the first hundred fathoms of depth into 5-fathom layers and enter in column (*A*) the mid-depth of each 5-fathom layer. For example, the first entry would be 4.5 fathoms, or the mid-depth between 2 and 7 fathoms, and similarly the entries for the following 5-fathom layers are 9.5, 14.5 fathoms, etc. Starting with 100 fathoms, enter the mid-depth for each 20-fathom layer for depths from 100 to 200 fathoms, disregarding now the depth of the acoustic unit below the surface, as for example, 110, 130 fathoms, etc. For depths deeper than 200 fathoms enter the mid-depth for each 200-fathom layer, as for example, 300, 500 fathoms, etc.

An adjustment is required at the deepest 5-fathom layer, below which the depth of the acoustic unit is ignored. Note that the 5-fathom layer whose mid-depth is 94.5 fathoms extends from 92 to 97 fathoms. This leaves a layer of only 3 fathoms whose mid-depth is 98.5. This adjustment must be carried over into column (*G*). (See (6) below.)

(2) Obtain the temperature and salinity values from the mean regional curves for the mid-depth of each layer in column (*A*) and enter them in columns (*B*) and (*C*) respectively.

(3) Derive the velocity for each temperature and salinity and depth, and enter the velocities in column (*D*). The velocities may be found from the tables in **9611**, or from the diagrams in **9612**. The method of deriving the velocities from the tables is described in **6343**. It is to be noted that each velocity of sound entered in column (*D*) is strictly applicable to the one depth entered in column (*A*) on the same horizontal line, but for the purpose of deriving velocity corrections it is considered to apply throughout the layer of which the value in column (*A*) is the mid-depth.

(4) Column (*E*) is ordinarily not needed for echo sounding. If mean velocities from surface to bottom are needed in R.A.R., the values in column (*D*) should be progressively meaned and entered in column (*E*), each entry being the mean of all the velocities down to and including that depth. In computing these means one should be careful of the transition from layers of one thickness to layers of another thickness.

(5) Derive the factors (see **561**) corresponding to each layer velocity and enter them in column (*F*). Table 35 in **9613** gives these correction factors for velocities of sound to the nearest meter and for instruments operating at three calibration velocities. Most instruments used by the Coast and Geodetic Survey are operated for a velocity of 820 fathoms per second and the correction factors can be taken from the table by interpolation. For the rare case of an instrument operated for any other velocity of sound the correction factors may be derived from the formula in **561**.

(6) Multiply each correction factor in column (*F*) by the layer thickness in fathoms, to derive the correction applicable to this depth interval. Enter these products in column (*G*). Each of these entries is the correction in fathoms for that layer, whose mid-depth is in column (*A*). Be sure to allow properly for the layer whose mid-depth is 98.5 fathoms—this layer, in the example, is only 3 fathoms thick, and the proper entry in column (*G*) is the factor multiplied by three—not by five, as for preceding values.

(7) Add the values in column (*G*) algebraically, entering the progressive sums with their correct signs in column (*H*); thus each entry in column (*H*) is the sum of all the values in column (*G*) on a line with and above it.

(8) For convenience enter in column (*I*) the depth of the bottom of each layer. This is the depth for which the entry on the same horizontal line in column (*H*) is the correction; any entry in column (*H*) is the total correction to be applied to a sounding whose depth is equal to the corresponding entry in column (*I*).

(9) The values in column (*H*) are then plotted with reference to the depths in (*I*) to which they apply and a smooth curve is drawn through them, from which curve the correction to apply to any sounding may be scaled (see **5614**).

### *5614. Velocity Correction Curves*

After the values in columns (*H*) and (*I*) in table 20 have been derived and entered, they shall be utilized to plot a graph of the velocity corrections. A commercial graph paper with overprint (Form *J*-100-5) shall be used for this purpose. This paper has 20 divisions to the inch. The overprint provides a vertical depth scale in fathoms for depths to 200 fathoms. When used for such depths the horizontal scale shall be 1 inch equals 0.4 fathom. For deep-water correction curves, both scales shall be multiplied by 10, adding a zero to the printed vertical scale, and making the horizontal scale 1 inch equals 4 fathoms. Where a deep-water correction curve is included on the same sheet with a shoal-water correction curve, the deep-water curve shall be properly identified. The form, with velocity correction curves drawn and a tabulation of the corrections is reproduced at reduced scale in figure 114.

Where velocity corrections in feet are required, the units on Form *J*-100-5 should be changed to feet and the scales used as "for depths to 200 fathoms."

After the values in column (*H*) have been plotted, smooth curves should be drawn through them and a tabulation of velocity corrections should be made for use in making entries in the Sounding Records (see **8223**). The tabulation should provide a depth range through which each correction is applicable. The units of the corrections depend on the depths and character of the area (see **821** and table 29). For example, if corrections

are required in units of tenths of fathoms, the change points should be taken at 0.05 fathom points, and these change points should be marked on the curve; thus, for example, if the correction +0.5 fathom is found to be on the correction curve at a depth of 75 fathoms, the correction +0.6 fathom at a depth of 85 fathoms, and the

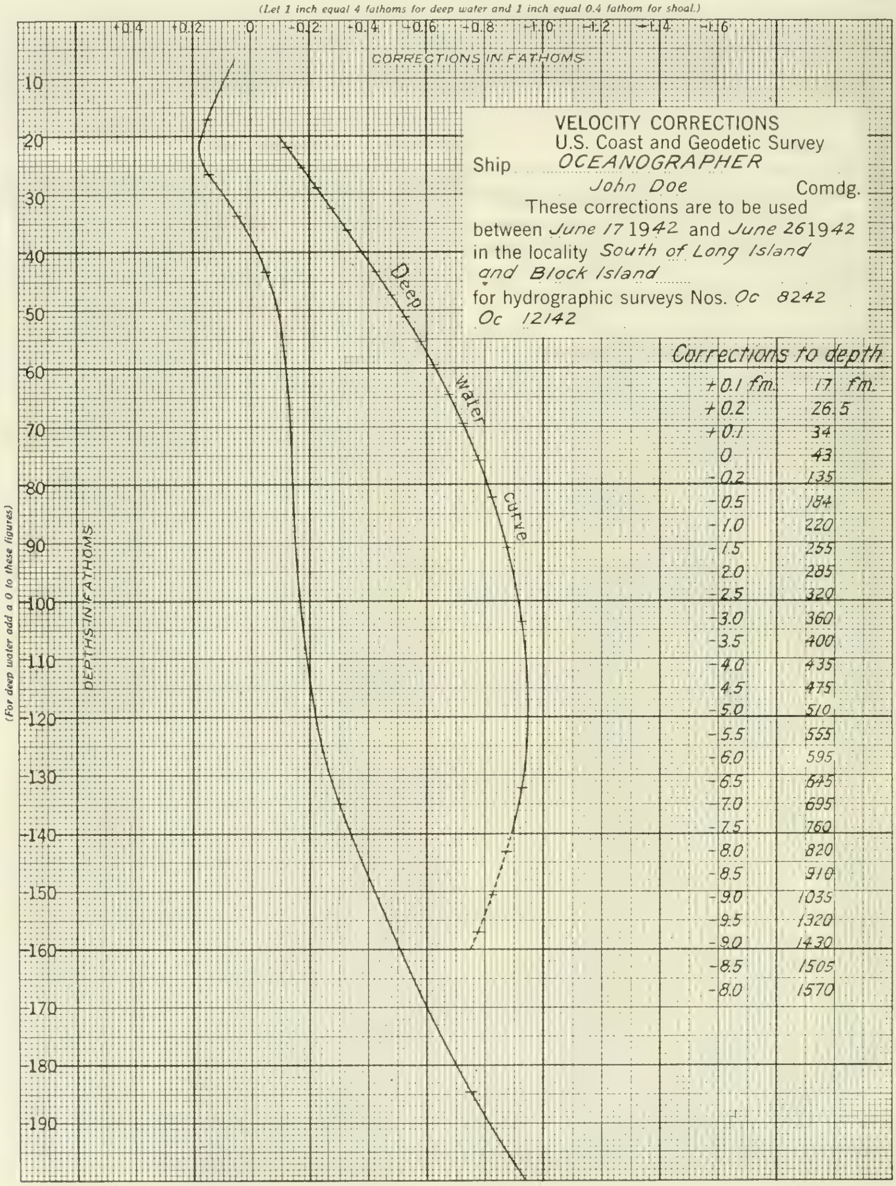


FIGURE 114.—Curve of velocity corrections to echo soundings.

correction +0.7 fathom at a depth of 95 fathoms, the tabulation should show that the correction +0.6 fathom is applicable for all depths from 80 to 90 fathoms.

These velocity correction curves should be included in the velocity of sound report (see **8332**), but a tabulation of the velocity of sound corrections shall be included in the Descriptive Report for each hydrographic survey (see **8434**).

### *5615. Graphic Determination of Velocity Corrections*

In the graphic method of determining velocity corrections, use is made of specially prepared graphs called "Velocity correction graphs." By their use the velocity correction curves (**5614**) can be plotted directly from temperatures and salinities derived for columns (*B*) and (*C*) of table 20, without recourse to any tables or arithmetic computations. After facility in their use has been acquired, the method is very much faster than that described in **5613**. It is even possible to use temperatures and salinities directly from the mean regional curves (**5612**), to find the corrections for plotting the velocity correction curves on Form *J*-100-5.

There are three velocity correction graphs, numbered *A*-1229-1, *A*-1228-1, and *A*-1230-1, for instruments calibrated for a velocity of sound of 800, 810, and 820 fathoms per second, respectively. Copies of these graphs are obtainable from the Washington Office. The velocity correction graph *A*-1230-1 is reproduced at a reduced scale in figure 115.

The graph utilizes temperatures in degrees centigrade as an ordinate, and a system of curves to represent salinities, with three abscissa scales giving the velocity corrections to be applied for depth layers of three thicknesses. The principle of utilization of depth layers is exactly the same as in the numerical method described in **5613**, except that in the graphic method no corrections for pressure are applied for depths less than 200 fathoms. Values taken from the graphs will, therefore, differ slightly from corresponding values taken from the tables, but the differences will not be enough to affect the ultimate accuracy of the corrections.

#### A. SCALES OF THE GRAPHS

The velocity correction graphs are designed for use directly with Form *J*-100-5 on which the velocity correction curves are drawn. They are constructed so that horizontal scales for the 20-fathom and 200-fathom layers correspond to the scales used on the above form (see **5614**). Where 5-fathom layer-intervals are used, the values taken graphically from the velocity correction graph must be divided by four to reduce them to the 20-fathom layer scale for use on Form *J*-100-5. This can be done by using proportional dividers instead of regular dividers when scaling the intercepts.

#### B. METHOD OF USE

Each velocity correction graph contains a vertical index line at which the correction is zero. It should be noted that the position of this index line and of the abscissa scales differs, with reference to the system of salinity curves, for the different standard velocities. In using the graphs one must be certain to use the graph corresponding to the calibration velocity of his echo-sounding instrument. In the rare case of an instrument operated for a velocity of sound other than one of the three standard velocities, the difference may be accounted for by using the graph for a standard velocity nearest that at which the instrument is operated, and moving the index line and the vertical grid lines in the following manner:

> For each fathom variation in velocity from the standard, move the index line 0.00602 fathom (on the 5-fathom layer scale)—to the right if the instrumental velocity is less than the standard, and to the left if it is greater than the standard. Any error due to this procedure is considerably less than one-tenth percent.

Before using the velocity correction graph, the approximate range of the corrections should be determined so that the zero of the correction curve may be properly placed on Form *J*-100-5. This is particularly necessary for the deeper depths where the curve is frequently a reverse one. It may be necessary, therefore, to determine graphically the positions of a few points on the velocity correction curve as a preliminary step.

*a. For depths of 200 fathoms or less.*—Using the mid-depth of each layer and corresponding temperature and salinity values, as in columns (*A*), (*B*), and (*C*) in table 20 of **5613**, enter the velocity correction graph with the temperature as an ordinate and find where it intersects the salinity curve for the corresponding salinity. On the edge of a strip of paper laid horizontally, mark off the intercept

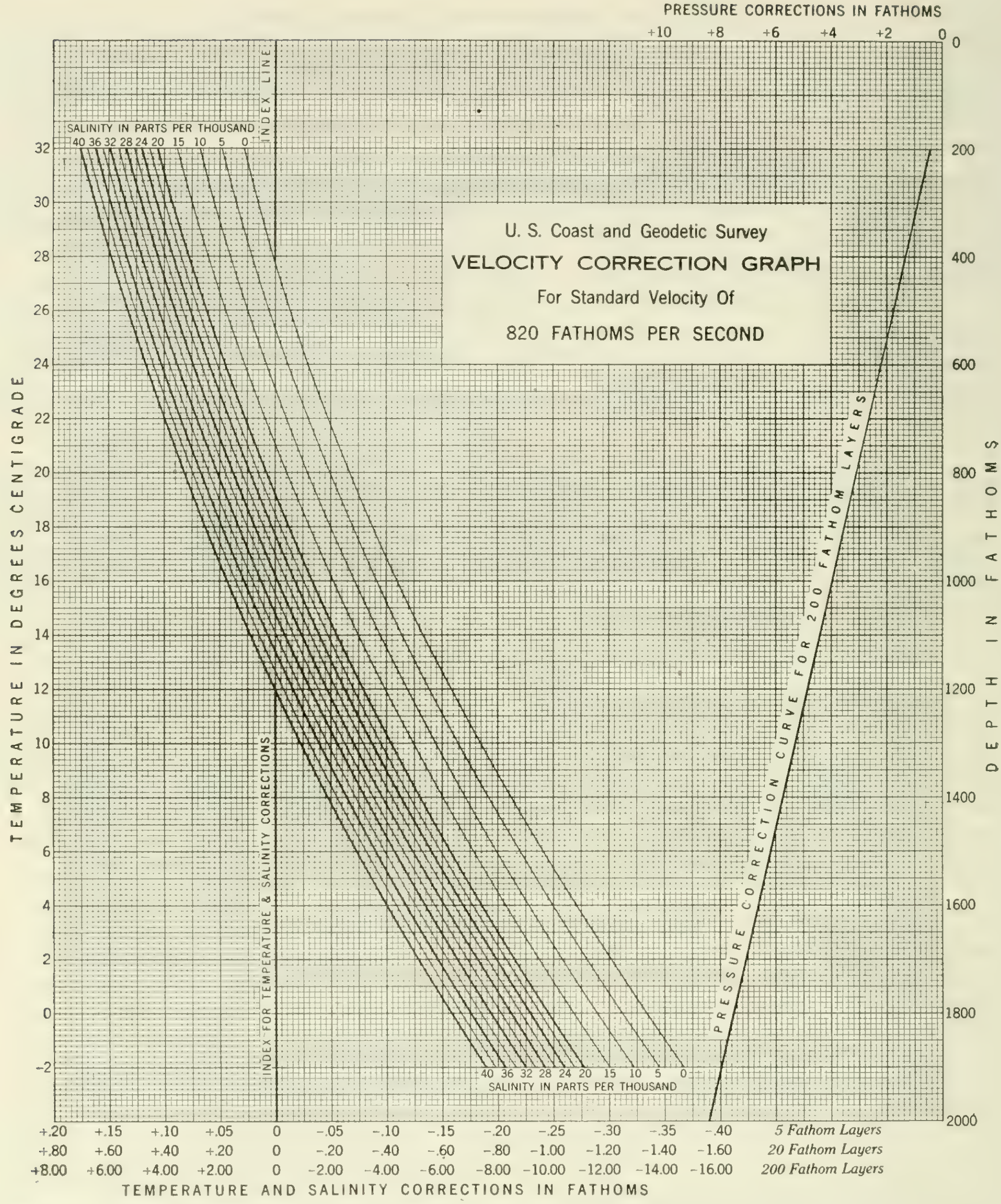


FIGURE 115.—Velocity correction graph. (Reproduced at reduced scale. Do not use this figure for deriving velocity corrections by the graphic method.)

from this intersection to the index line of the graph, and transfer this distance to Form *J*-100-5 in the proper direction at the depth of the bottom of the first layer (i. e., just as in the numerical method, in which the layer correction must be plotted at the depth shown in column (*I*)). This gives one point on the desired velocity correction curve. As explained under "Scales of the Graphs," where 5-fathom layer-intervals are used, the intercept must be divided by four prior to plotting on Form *J*-100-5.

Proceed in like manner for the second layer, except that the intercept is added graphically to the distance already laid off on the strip of paper for the first layer, always being careful to observe the sign of the correction. Transfer the resultant total distance to Form *J*-100-5 at the appropriate depth for the second layer.

Follow the above procedure for other layers until the entire depth range has been covered.

Instead of a strip of paper a pair of dividers can be used, successive intercepts being added or subtracted mechanically by increasing or decreasing the span of the dividers.

It is to be noted, as mentioned above, that no correction for pressure is included for depths less than 200 fathoms.

*b. For depths greater than 200 fathoms.*—The use of the velocity correction graphs for depths greater than 200 fathoms is exactly the same as described above, except for an additional correction for pressure. Near the right-hand edge of the velocity correction graph is a diagonal line labeled "Pressure Correction Curve for 200-Fathom Layers." This curve is based on corrections computed for 200-fathom layers at the standard velocity of the graph, each correction being based on the mean depth of the layer; thus, the pressure correction of 4.8 fathoms (fig. 115) read on the curve opposite 1,200 fathoms is the correction for the 200-fathom layer between 1,000 and 1,200 fathoms, computed for a mean depth of 1,100 fathoms.

For depths greater than 2,000 fathoms, a pressure curve can be readily constructed by transferring the intercept for 2,000 fathoms (at the bottom of the graph) to the top of the graph and drawing a line parallel to the printed pressure curve.

For the first point on the deep-water correction curve at 200 fathoms, scale the correction for 200 fathoms from the shoal-water correction curve already prepared and divide it by 10 to adapt it to the deep-water scale. Lay this distance off on the edge of a strip of paper, taking care to mark the correct end zero and the value of the correction with the correct sign (plus to the left and minus to the right). To this value apply graphically the correction at 200 fathoms from the pressure correction curve (it will be noted that all corrections for pressure are plus and should be applied to the left), transferring the resultant to Form *J*-100-5 at 200 fathoms (deep-water scale).

Enter the velocity correction graph with the temperature and salinity for the mid-depth (300 fathoms) of the next layer, and apply in the proper direction the resulting intercept graphically to the previous distance on the paper strip. Then set the paper strip on the pressure curve at 400 fathoms and from the last mark on the strip apply the pressure intercept graphically. The resultant distance from the zero on the strip will be the distance to be laid off at 400 fathoms on Form *J*-100-5.

Proceed in like manner for other layers to the deepest depth required.

The construction of a deep-water curve is simplified where it is possible to transfer the pressure correction curve from the velocity correction graph to Form *J*-100-5. In such cases the corrections for temperature and salinity are laid off from the pressure curve as an initial, instead of from the zero of the velocity correction curve. As each point on the curve is plotted, its distance from the zero line of the curve must be marked on the strip of paper before the next intercept for temperature and salinity is added graphically to it, the total distance being laid off from the transferred pressure curve as an initial. An analysis of this graphic method of summation will make it clear why this must be done. Each horizontal distance plotted on the velocity correction curve in this manner must consist of the summation of all the corrections for temperature and salinity, and all the pressure corrections except the final one, the latter being accounted for by the transferred pressure correction curve. This possibility of utilizing the pressure correction curve should be kept in mind when fixing the zero of the velocity correction curve on Form *J*-100-5.

*c. For shoal-water depths.*—Where corrections in feet are desired, it is necessary to change all units from fathoms to feet on both the velocity correction graph and on Form *J*-100-5. The corrections for 5-fathom layers printed at the bottom of the correction graph will then be in feet, and for 5-foot layers. Likewise, the horizontal scale of Form *J*-100-5 will be 1 inch equals 0.4 foot, but the horizontal scale of the velocity correction graph will be 1 inch equals 0.1 foot. Therefore, each distance scaled from the velocity correction graph must be divided by four before being plotted on Form *J*–100–5. This may be done conveniently by using proportional dividers to scale the intercepts.

When determining velocity corrections in feet, it will also be found convenient to prepare the temperature and salinity curves in feet instead of fathoms.

After the velocity correction curves have been determined, the procedure is the same as for the numerical method (see **5614**).

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### *5616. Instrumental Adjustment to Account for Velocity*

All echo-sounding instruments used by the Coast and Geodetic Survey are operated at a constant motor speed for a selected velocity of sound known as the calibration velocity, and subsequent corrections are made for any difference between the actual and the calibration velocity. It is possible to allow for the velocity instrumentally if the average value of the velocity of sound is known in advance. Assuming that the index is properly set to account for the draft of the acoustic units (see **554**), it is possible to regulate the speed of the registering device, or to change the position of the index on the scale, so that the registered depths need no further correction for velocity. The latter method may be used in limited degree on some of the echo-sounding instruments used by this Bureau (see *a* below). Instruments have been designed and used which are provided with a simple means of altering the speed of rotation of the driving motor to make the registered depths correct for the assumed velocity conditions (see **529**).

Adjustments of this nature are of restricted application. A rather detailed knowledge of the average velocities of sound in the project area must be available *before* actual sounding. Furthermore, since the velocity of sound usually varies with depth, the use of such an adjustment is only applicable throughout a limited range, and presupposes a knowledge of the depths to be measured.

*a. Compensation by index setting.*—For shoal-water sounding, where the range of depths sounded is limited and reliable results are obtained by bar check (see **557**), it is possible to adjust the index to compensate for the error of soundings at a mean depth of the range. This method of compensation may be used where no residual error greater than 0.25 foot in depths less than 10 fathoms or greater than one-half percent in depths greater than 10 fathoms is left at either limit of the range of depths. For example, if the range of depths sounded is from 10 to 60 feet, and the bar check discloses an error of 0.5 foot at 10 feet and 1.0-foot error at 60 feet and other errors are proportional or nearly so, the index can be adjusted to compensate for the error of 0.75 foot at 35 feet, leaving residual errors of 0.25 foot of opposite signs at the limiting depths of 10 and 60 feet. Or, if the range of depths sounded is from 10 to 20 fathoms, and the bar check discloses errors of 0.1 and 0.25 fathom at 10 and 20 fathoms respectively, and other errors are proportional or nearly so, the index can be adjusted to compensate for an error of 0.15 fathom at 13⅓ fathoms, leaving residual errors of 0.05 and 0.1 fathom of opposite signs at the limiting depths of 10 and 20 fathoms respectively, the error in each case being one-half percent of the depth.

### *5617. Velocity Corrections by Bar Check*

For sounding in shoal water, the bar check (see **557**) can be used to derive corrections applicable to the various depths. With the index of the instrument properly adjusted (see **5545**), the results of accurate bar checks may be used to plot correction curves for use in correcting the registered depths. Only bar checks taken under the most favorable conditions are considered sufficiently accurate for this purpose. When used for this purpose, the mean differences between the bar depths and the registered depths at each depth shall be used as a correction to apply to all soundings of that depth. These differences resulting from the bar check should be plotted as a correction curve. The hydrographer must use his judgment as to whether the results of a number of bar checks should be averaged to be applied over a considerable period of time, or whether the result of the bar check at the beginning of the period should be averaged with that at the end of the period for application to the soundings taken between bar checks.

It should be emphasized that this method is not to be used except when exceptionally good results are obtained from the bar checks and they are consistent enough to give reasonable assurance that the greatest part of the difference is due to the velocity of sound. Furthermore, the method is applicable only where the range of the bar depths nearly covers the range of depths sounded. Velocity corrections must not be extrapolated from a correction curve so obtained, for depths greater than one-third more than the range of the bar checks.

### 562. Mechanical Corrections to Fathogram Soundings

An instrument has been designed in the Coast and Geodetic Survey by which depths can be scaled from the fathogram of an 808 Fathometer fully corrected for tide, phase, and index setting, and approximately for the velocity of sound. The instrument consists of a small bench with a reel at each end to hold the fathogram record spools, between, which is a platen across which the fathogram may be moved, assimilating its movement at the time the record was made on the echo-sounding instrument. As the fathogram is moved across the platen, it passes under a circular piece of transparent plastic about 10 inches in diameter, on which is inscribed a circular graduated scale covering the entire range of depths (0 to 160) of the 808 Fathometer. The scale is graduated for the calibration velocity of 820 fathoms (or approximately 1500 meters) per second, but the circular plastic scale is removable, and others are provided with scales graduated for velocities of sound at 15-meter intervals, i. e., for velocities of 1470, 1485, 1515, etc., meters per second.

The radius of the circular scale is exactly equal to the length of the stylus arm of the Fathometer, so that the circumferential arc of the scale corresponds to the arc described by the stylus across the fathogram. Provision is made for keeping the fathogram alined horizontally with the center of the scale. For scaling any given recorded depth, the center of the circular scale will occupy the same relative position as was occupied by the center of the stylus arm at the time the record was made.

On the periphery of the plastic scale are four groups of graduations, each ranging from +5 to −20, to provide for tide corrections for the different phases of the instrument (see **5232**).

In scaling depths with this instrument the printed scale on the fathogram is ignored. The following four adjustments are provided: (1) The circular plastic scale can be moved vertically, with reference to the fathogram, to make the circular scale coincide with the arc drawn by the stylus arm; (2) the scale can be rotated to set the zero of the scale correctly with reference to the recorded position of the transmitted signal on the fathogram; (3) it can be rotated also to correct for the height of tide; and (4), it can be rotated to scale depths from any one of the four depth phases which the instrument provides, without disturbing the above three adjustments.

The 808 Fathometer operates at a calibration velocity of 820 fathoms per second, and a scale graduated for this calibration velocity is provided. But by changing scales and always using the scale for the velocity of sound nearest to the average which existed from surface to bottom in the depth sounded, no error exceeding one-half percent of the depth will be introduced by this method of correcting for velocity.

Or if accurate bar checks have been obtained throughout the range of depths sounded (see **5617**), a scale can be selected to fit the record of the bar check without any reference whatsoever to the velocity of sound.

### 563. Errors Caused by Bottom Slope

The transmitting and receiving units of echo-sounding instruments using sonic frequencies are generally nondirectional (see **5152A**), and those which utilize supersonic frequencies are usually made more or less directional. When a sound impulse emanates from a sonic transmitting unit, the sound is propagated in all directions in the medium and the first echo that is registered on the indicator of the echo-sounding instrument will have traveled to the bottom and back by the shortest possible route—in other words, it will have been reflected from the bottom surface nearest to the vessel that offers a normal reflecting surface. Where the sea bottom below the vessel is sloping, the shoalest registered echo sounding, theoretically, will not have been reflected from vertically below the vessel, but from some point on the slope which is some little distance away horizontally.

Echo-sounding errors caused by the slope of the sea bottom present an exceedingly complex problem because of the wide range of conditions encountered in actual practice. Such an error depends on (*a*) the slope of the bottom with respect to the horizontal; (*b*) the depth of the water; (*c*) the shape of the bottom; (*d*) the reflecting characteristics of the bottom; (*e*) the dimension of the cone of sound transmitted if the transmitting unit is directive; (*f*) the frequency of sound transmitted; (*g*) the intensity of the transmitted signal; and (*h*) the sensitivity adjustment of the instrument.

Where the slope that the bottom makes with the horizontal is known, the true depth at the place of sounding can be theoretically determined by applying a correction to an echo depth obtained on a sonic instrument in one of a number of ways all of which, however, employ the basic relation

$$h=\frac{e}{\cos\theta}$$

in which $h$ is the vertical depth under the vessel, $e$ is the echo depth registered on the echo-sounding instrument, and $\theta$ is the angular slope the bottom makes with the horizontal.

The determination of the angular slope of the bottom is by no means a simple matter. It is sometimes difficult to realize when examining a line of echo soundings, and particularly the profile so distinctly shown on a fathogram, that it is not a true line profile, or section. It is actually a composite profile made up of echoes reflected from many points of the bottom, some to one side and some ahead or astern, within the effective cone through which the sound from the oscillator is radiated as the vessel moves over the water surface. The diameter of the area on the sea bottom, covered by this cone, depends on the angular spread of the transmitted sound and the depth of the water. The width of the band effectively sounded along the track of the vessel over a flat horizontal bottom is given by

$$w=2d\cdot\tan\theta$$

in which $w$ is the diameter of the cone at the sea bottom, $d$ is the depth of water, and $\theta$ is the angle between the edge of the cone and the vertical. This is on the assumption that echoes are received from all points of the area within the cone, probably an infrequent occurrence as only a fraction of the reflected energy is received.

To make accurate corrections for the slope of the bottom would, therefore, require detailed knowledge of the submarine topography. For many types of bottom, fairly

accurate corrections can be deduced from the depth contours based on uncorrected echo soundings. The problem can be dealt with either by moving the echo sounding to a point vertically over the echo point and reducing it to give that depth, or by increasing it to give the vertical depth below the vessel. In either case, methodically correcting the soundings on a survey sheet is a laborious task.

In areas of irregular bottom, it is not possible to reconstruct from uncorrected echo soundings a profile or series of depth curves of sufficient accuracy for this purpose. The actual point on the bottom from which the echo for a particular sounding is reflected cannot be easily determined, and regardless of the intensity of a survey in deep water, detailed contours drawn will not always disclose whether the survey has been intense enough to justify the use of depth curves for the correction of echo soundings. In a steep submarine canyon the echo of a sonic instrument would never come from the deepest portion of the canyon as long as the distance from the survey vessel to the sloping sides is less than the vertical depth below the vessel; in such a case there is no practical correction that can be made. If the echo soundings are corrected on the basis of the slope of the side of the canyon, there is always a likelihood of showing either a greater or lesser depth than actually exists in the deepest part of the canyon, and seldom will the true depth be indicated.

It is therefore obvious that something more than a mere detailed contour sheet based on the echo soundings is required to make a rational analysis of the corrections to be applied for slope to deep-water soundings in areas of irregular bottom. By making certain assumptions, one European investigator has proposed the construction of profiles of the individual sounding lines, with equal vertical and horizontal scales, and from these and the contour sheet the corrections are to be deduced. This is an elaborate method and its use depends on the closeness of the spacing of the sounding lines. The method may find application in thoroughly surveyed regions where, for scientific purposes, the closest possible approximation to the true bottom configuration may be desired, which could not be obtained from the depth contours alone. This would require, particularly in an area of irregular bottom, a much more intensive survey than is needed for navigation and for general hydrographic surveys. The method would not be justifiable.

A practical solution to the problem would be to study the uncorrected echo soundings in a given area, and where the study discloses that the echo soundings by themselves are not adequate for representing the bottom configuration, to supplement them by a number of vertical soundings. This should be done on steep slopes contiguous to gentle slopes and in submarine valleys and canyons.

The nautical charts resulting from hydrographic surveys are made for the use of the mariner. While, from a purely theoretical viewpoint, a correction should be applied to echo soundings for errors caused by slope, there are several practical reasons why this is neither desirable nor necessary.

The depth at any point is represented on a chart by a numeral and not by a point. From the viewpoint of the practical navigator then, there is no advantage in correcting an echo sounding to verticality if at the scale of the chart an actual depth of water equal to the uncorrected echo sounding would be found at a small horizontal distance away, especially if this distance on the chart is normally covered by the height and width of the numerals representing the sounding. In the practical application of this principle it will be found that the corrections for slope will be automatically eliminated from a large percentage of soundings. This is more fully explained in Special Publication No. 165, Slope Corrections for Echo Soundings.

Another consideration to bear in mind is that echo-sounding instruments are being used increasingly for navigation, and if the navigator uses a sonic instrument he also will read uncorrected depths. If from a survey vessel at a given point an echo sounding is obtained with an error due to bottom slope, and this uncorrected depth is charted, it will represent the depth which the navigator will obtain on his instrument at the same point. If such soundings should be corrected for errors due to slope, it would be necessary for the navigator to reverse the correction process or to apply corrections to the echo soundings he obtains before he could utilize the charts.

Because of the complexity of the problem and the difficulty of applying slope corrections rationally, especially in irregular bottom, slope corrections should not be made by field parties except as specifically directed in the project instructions.

In areas of irregular bottom and steep slopes, the reflected echo is often registered on the echo-sounding instrument indistinctly, or as a multitude of depths scattered along the scale, one of which may be the true depth. On a visual instrument the selection of this true depth is virtually impossible, due to its confused character and the fact that the observer has no time for analysis. On the fathogram of a graphic-recording instrument, however, the characteristics of such soundings appear more clearly, and there is a permanent record of them from which a deliberate study may succeed in selecting the true vertical depth, or one near it. At any rate the evidence of what was registered on the instrument is permanently recorded so that the results can be more properly evaluated than is possible from a series of depths recorded in a Sounding Record.

In connection with bottom slopes, caution is necessary in examining fathograms of graphic-recording instruments. Because of the exaggerated vertical scale one is apt to be startled by the steep slopes depicted and to think of them as representative of the actual submarine relief. This is far from true since it is customary on most fathograms to have the vertical scale increased many times with reference to the horizontal scale. For the fathogram of an 808 Fathometer the vertical scale along the arc is about 45 times the horizontal scale for a record made from a vessel traveling at 7 knots, and about 65 times for a vessel traveling at 10 knots. From these relationships the relation of the vertical scale to the horizontal for other vessel speeds can be computed.

## 57. ECHO-SOUNDING INSTRUMENT OPERATION

Although the fathometer attendant is not expected to be able to repair and make mechanical adjustments to an echo-sounding instrument, he should be familiar with the principles of operation of the instrument he is using; and he should follow certain precautions in operating the instrument and in reading the registered depths in order that the recorded values may most accurately represent the true depths.

The various precautions to be observed in operation and in reading the registered depths are described in chapter 3 and in this chapter, but they are summarized here for convenience, and unless otherwise noted apply to all echo-sounding instruments described in this Manual.

(*a*) The gain control must be adjusted at the highest value that will not produce excessive strays or cause oscillation of the amplifier, and it should be maintained at this value, except when it is necessary to change it for the proper registration of soundings. This setting should be the same as was used in any determination of the instrumental error or in any comparative soundings (see **552**). It must be borne in mind that a readjustment of the gain control alters the position of registration on the depth scale. (See **5163**.)

(*b*) The motor speed must be kept at the correct calibration value (see **555**). For instruments with reed tachometers this is when the middle reed is vibrating at maximum amplitude. For graphic-recording instruments the motor speed must be kept continuously at the correct value. For visual instruments the fathometer attendant must see that it is correct at the time each sounding is read.

(*c*) On a visual instrument where the depth is indicated by a line of appreciable width, the shoal edge of the line must be read (see **5543**). On a graphic-recording instrument where the depth is indicated by a jog or offset from a continuous line the depth is indicated by the very beginning of the offset mark.

(*d*) Regardless of the sounding interval, the fathometer attendant must observe continuously the depths registered on a visual instrument in shoal water or wherever there is the slightest possibility of the existence of dangers or obstructions, in order to make certain that none of these is missed (see **3415**). In one test that was made with the 312 Fathometer on a vessel proceeding at standard speed over a known shoal with depths of 7½ fathoms rising from general depths of about 40 fathoms, the shoalest depth was registered by only one flash of the neon tube, preceded and followed by only one or two faint flashes from intermediate depths. These latter might easily have been mistaken for strays.

(*e*) Using a visual instrument the fathometer attendant must be certain that he is not reading a multiple echo (that is, a second or third echo instead of the first). This is particularly important where sounding is begun in comparatively deep water where even the approximate depth is not known.

(*f*) Where rapid fluctuations in registered depths are known with certainty to be caused by the vertical motion of the vessel in rough weather, a mean depth shall be recorded (or scaled from a fathogram) which is as near as possible to what the depth would have been had the sea not been rough. But where rapid fluctuations in registered depths are caused by bottom irregularities the shoalest of these occurring near the time for a sounding shall be recorded or scaled.

(*g*) Regardless of the sounding interval an intermediate depth must be recorded, or scaled, wherever the intermediate depth differs from the normal slope of the bottom by more than 5 percent of the depth (see **3433**).

(*h*) The fathometer attendant must learn to distinguish between an echo from the bottom and a stray. Usually, but not always, the true echo on a visual instrument is slightly brighter in intensity than the strays. Generally, strays appear on the dial at random and thus can be distinguished from echoes, but under certain conditions strays may be repeated at the same place on the depth scale, thus resembling soundings (see **5147**).

(*i*) In sounding over irregular bottom where the slopes are steep, and particularly in comparatively deep water, several echoes from different parts of the slope are often registered almost simultaneously on a visual instrument. These appear on the dial as a splattering of the light from the neon tube. Theoretically at least, the shoalest depth registered on a sonic instrument should be from that part of the bottom nearest to the vessel, regardless of verticality. This obviously is not the true depth. Under certain circumstances, however, the true vertical depth may be registered as a deeper value. In such cases a notation should always be made in the Sounding Record, describing the appearance of the registration on the instrument and stating which value was recorded. (See also **5145** and **563**.)

(*j*) If an allowance for settlement and squat has been made when the index was adjusted, any soundings taken from the vessel stopped or at slow speed must be corrected arithmetically for this allowance (see **553**). The fathometer attendant must note in the "Remarks" column of the Sounding Record all such soundings for which this correction is required.

(*k*) Rubber Stamp No. 31, Graphic Record, must be impressed at the beginning and end of each fathogram roll, and at the beginning and end of each day's work on the fathograms; entries must be made in all applicable spaces. Figure 116 is a facsimile of this stamp with entries properly made.

## 571. Fathogram Interpretation

With a graphic-recording echo-sounding instrument a continuous and permanent profile of the bottom is obtained. No trouble is experienced in scaling depths with the required accuracy from the majority of fathograms. But certain precautions in operation during sounding are required, certain recorded evidence should be explained on the fathogram by the hydrographer, and certain skill in interpretation is required, in order that the greatest value and the most accurate results are obtained from the records.

The following instructions apply generally to all fathograms, but particularly to the 808 Fathometer. The fathograms illustrated to which reference is made in the text were all recorded on the 808 Fathometer.

*a. Effect of gain adjustment.*—A variation of the gain control causes a decided change in the recorded depth. (See **57**(*a*).) Tests of one 808 Fathometer in depths up to 50 feet have proved that a change of one division in the adjustment of the gain control in the operating range (7 to 8) causes a change of about one-half percent in the recorded depths; also, a change of about 0.1 foot in the recorded position of the transmitted signal. As repeatedly emphasized in this chapter, the instrument must be operated as much as possible at a constant gain setting—the maximum possible without the introduction of excessive strays. Corrections should be computed for any variation of sensitivity for recorded soundings in critical depths, if such corrections affect the soundings appreciably.

**No. 31 GRAPHIC RECORD**

**Sheet No.** Oc-2341 **Recorder No.** 808-56

**Locality** Casco Bay, Maine

**Vessel** Stbd Motor Sailer

**From Pos. No.** 1-G **Date** July 18, 1942

**To Pos. No.** 96H **Date** July 19, 1942

**Jagged profile ~~(not)~~ caused by seas.**

L. C. Jenkins **Operator**

**Tide reducers by:** J. A. S. **Checked by:** A. A. N.

FIGURE 116.—Facsimile of stamp used on fathograms.

Improper gain adjustment is illustrated at (5) in figure 117 by the prolonged record made by the stylus after the receipt of the echo, and previously in the upper right corner of *A* by the excessive width of the transmitted signal. In an attempt to obtain a more clear-cut record the amplifier gain was increased excessively, causing oscillation of the amplifier. Excessive gain is also illustrated in *J* in figure 119. Note the strays caused near (34) in figure 119 by this excessive gain.

Four changes in gain adjustment are apparent in *L* in figure 119. At (38) the gain was increased, as is evidenced by the wider and darker record of both the transmitted signal and the echo; a further increase in gain resulted in oscillation of the amplifier at (37); a decrease in gain at (36) and an increase at (35) caused a lightening and darkening, respectively, of the trace of both the transmitted signal and the echo.

*b. Variation in motor speed.*—A variation from the correct motor speed produces a directly proportional error in the recorded soundings. It is, therefore, important for the hydrographer while sounding, and the cartographer while plotting the smooth sheet, to check the travel speed of the paper occasionally in accordance with **5554**.

Irregular speeds caused by poor governor control may result in a record very similar either to one produced by echoes from marine growth or to one produced while sounding in a short regular chop. A sudden sharp peak in the record may be caused by a momentary sticking of the governor contacts of the motor. Such a fault can cause a record, as in (27) in figure 118, which resembles a pinnacle. Note that this is not a stray because the double echo is plainly evident at (28) and this evidence would be lacking if (27) were a stray. Or such a fault can cause a sudden depression in the record. Such a change in speed is readily detectable by ear, although the noise of the launch engine may make it go unnoticed. When such a change is detected however, it should be noted on the fathogram.

*c. Faulty instrumental operation.*—A sudden sharp depression or elevation in the record of the bottom, where accompanied by a change in the recorded position of the transmitted signal, is not a hole or shoal on the bottom, but an instrumental fault probably caused by a sudden shifting of the transmitting contact due to a looseness in the locating pin or shifting of the phasing head. Such an instrumental fault is probably illustrated at (39), (40), and (41) in figure 119. Note that each time this occurs in the record of the bar check it also occurs in the record of the transmitted signal. Furthermore, that the instrument is operating poorly is evidenced by the ragged appearance of the line recorded by the transmitted signal.

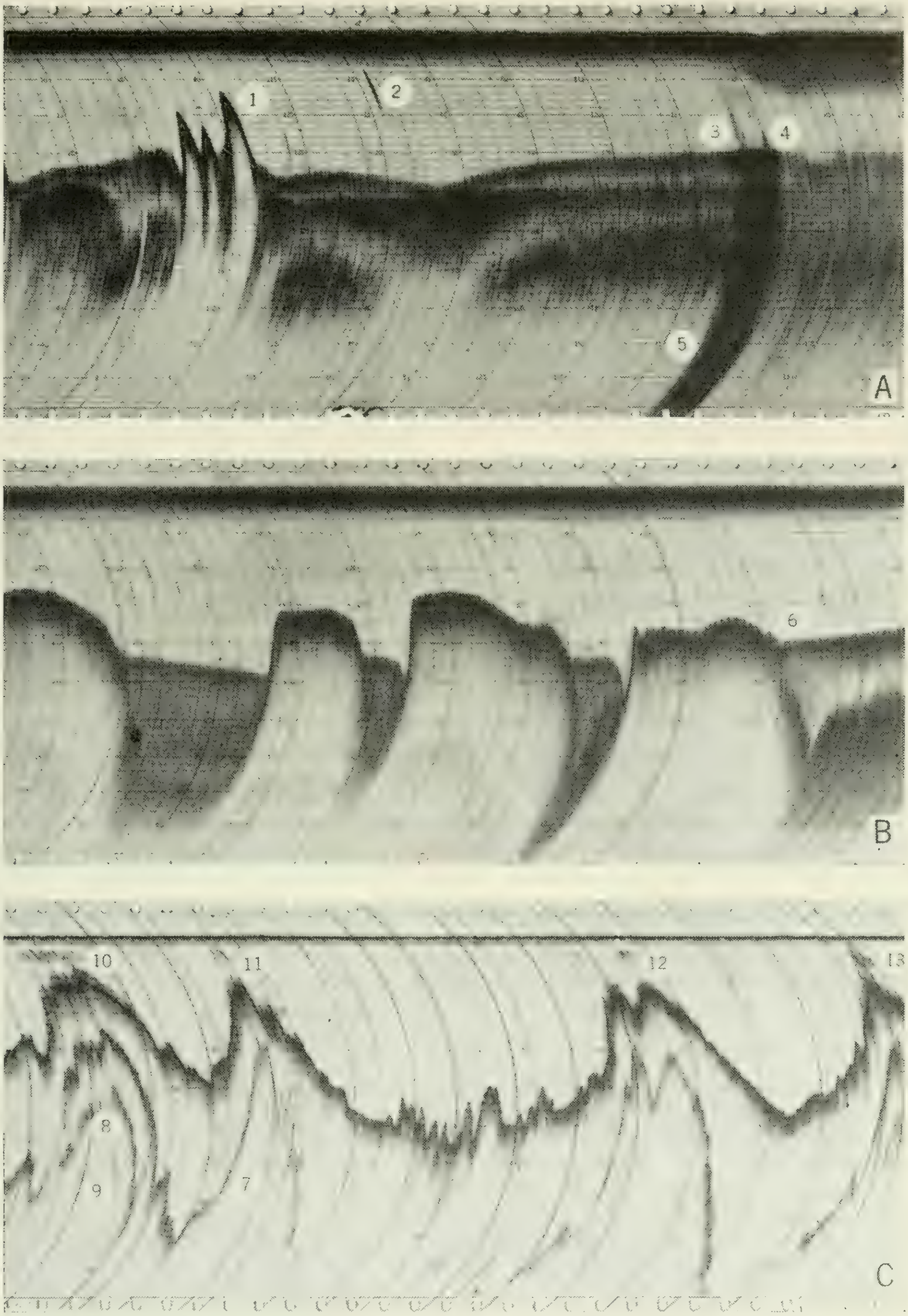


FIGURE 117.—Types of bottom relief shown vividly in fathograms of the 808 Fathometer.

*A* shows hard bottom protruding through soft bottom. *B* shows silt-filled depressions. *C* shows rugged bottom and is an interesting example of multiple echoes. The second echo is marked 7, the third is marked 8, and even the fourth is visible at 9. The trace above each shoal is from kelp. Note that the scale of *A* and *B* is six times that of *C*. See text for number references.

Insufficient pressure of the stylus will sometimes cause the instrument to cease recording for very short intervals, usually preceded by intervals during which the stylus marks only faintly. An example of faulty stylus pressure is illustrated in *F* in figure 118, where the stylus did not record at (23) near the right-hand side of the record. This is another example of excessive amplifier gain, probably accompanied by regeneration of the amplifier. Note how much wider the trace of the transmitted signal is at (24) than at (25).

A poor contact in one of the several mechanical contacts may be responsible for no signal being recorded. An example of this is illustrated in *E* in figure 118. Note that at (20), (21), and (22), and at several other places the record is momentarily lacking. That this instrument is faulty in operation is evidenced by the ragged line made by the transmitted signal.

Carbon nodules occasionally form on the platen over which the record paper travels and these cause horizontal marks to be traced through the fathogram as at (33) in figure 119. Several such marks are also evident in *F* in figure 118. The platen should be cleaned and polished daily in accordance with **5237***b*, or more often,if necessary to remove the trouble.

*d. Types of bottom.*—Bottoms of different types record characteristic echoes; hard bottom may be recognized by a shorter and blacker mark than soft bottom. The longer and fainter trace from the latter is because of the low density of the soft mud which permits a certain penetration of the signal, the echo being received from the true bottom and a multitude of depths immediately beneath. This difference is vividly illustrated in *B* in figure 117 where the depressions are evidently filled with material of varying density, and invariably the trace of the echo reflected from these is much longer than from the rocky portions between them. The same thing is illustrated in *A* in figure 117 where at (1) there is an intrusion of hard material through several sedimentary layers.

In extremely steep and broken bottom, echoes from slopes may sometimes be recorded. Under exceptional circumstances the echo from a slope may block out the true vertical echo, distorting the profile. (See **563**.)

A slope may be so steep that no echo from it will be recorded, particularly if the Fathometer is being operated on the fathom scale. Such a case is illustrated at (26) in figure 118 where no echo has been received from the left-hand side of the slope. A critical examination of the trace will disclose that there is an appreciable horizontal distance between the edge of the top of the slope where the echo is lost and the bottom of the following deep from which the echo again registers.

Because of the great exaggeration of the vertical scale at launch sounding speeds, slopes that appear to be nearly vertical from the record will, after careful scaling and analysis, become rational. (See **563**.)

Reflections from the sides of a depression can give a record which resembles a layer of silt over the depression, somewhat similar to that illustrated at (6) in figure 117. It must be borne in mind that such echoes can come from slopes to one side, as well as from ahead or astern, and that the dimensions of the features in this direction are not evident from the profile. Where deposits of silt are rare, such indications should be investigated by vertical leadline or wire soundings.

*e. Evidence of shoals.*—Over submarine topography of a rugged nature, in areas of heavy submerged, or floating, kelp or other marine growth, and when the Fathometer is not operating properly, the hydrographer must make a careful study of the indicated shoals before accepting or rejecting them. The study of similar records in which shoal indications have been checked with the leadline is helpful but not always conclusive.

True shoals in extremely irregular bottom can generally be distinguished by the fact that there is no evidence of a record of the bottom through the base of the trace of the shoal. In other words, the trace of a true shoal appears as a Λ with an opening in the trace at its base. This is illustrated in *D* in figure 118, more especially at (14), (15), (17), (18), and (19). This record warrants careful study. Also note that the trace at (16) is from a true shoal, although the open Λ at its base is not so apparent, because it is filled by the trace of the double echo.

*f. Reflections from kelp or other marine growth.*—Probably the fathograms that are most difficult to interpret properly are those in which echoes from kelp, or other marine growth, appear; particularly where the kelp is well submerged. Where the main bulk of the kelp floats at some distance above the bottom, the trace from the kelp appears to be detached or semidetached from the bottom with the result that the bottom trace is partly obscured and reduced in intensity although it is still possible to follow its outline. An excellent example of kelp on shoals, the character of which there is no doubt, is illustrated in *C* in figure 117. On every shoal near the surface, at (10), (11), (12), and (13), kelp is growing and its trace is shown in the record, yet there is no doubt about the true bottom at some depth below the kelp. At (32) in figure 119 the trace from the kelp, or other marine growth, almost

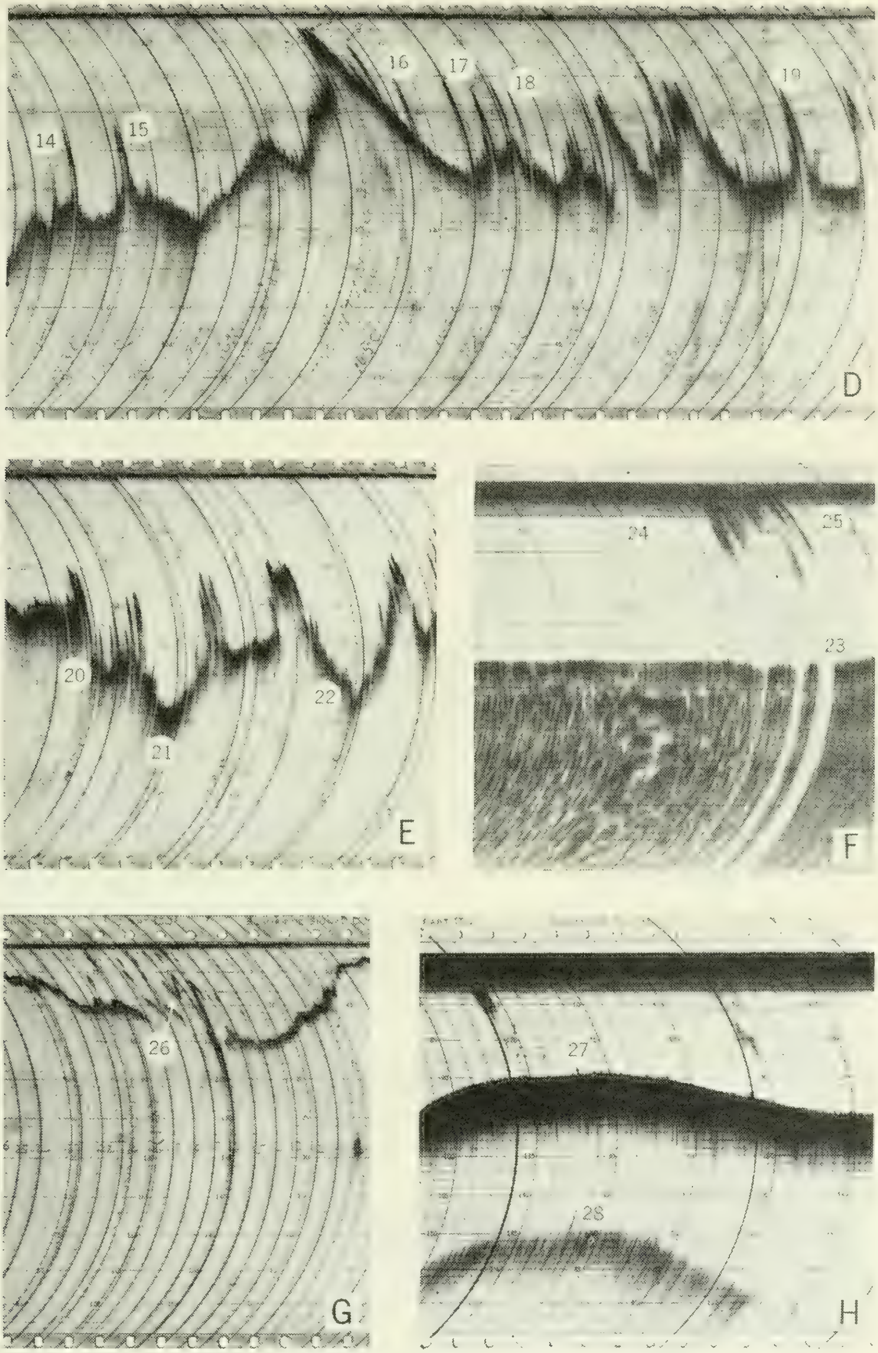


FIGURE 118.—Various interesting fathograms of the 808 Fathometer.

Extremely rugged bottom appears in *D*, *E*, and *G*, and the second echo has recorded plainly in *H*. These fathograms are discussed in the text and referred to by the reference numbers. Note that the scale of *F* and *H* is six times that of *D*, *E*, and *G*.

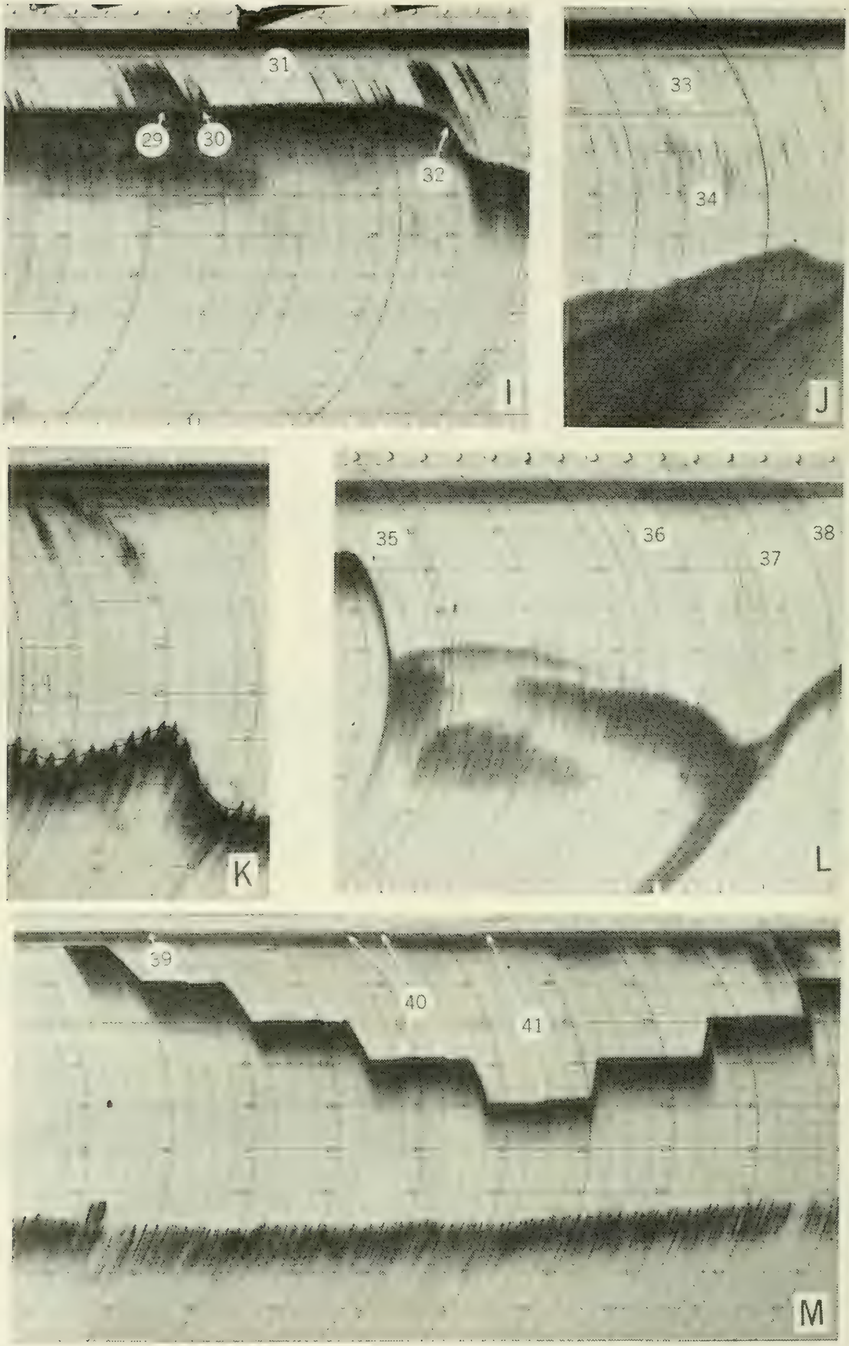


FIGURE 119.—Interesting fathograms of the 808 Fathometer.

*I* shows marine growth on almost flat bottom. *K* shows irregularities caused by the vertical motion of the hydrographic launch due to a ground swell—the average of the peaks and valleys should be scaled where this is known to be the cause. *L* is an example of very soft surface bottom. *M* is an illustration of a bar check (see **557**). The scale of all fathograms in this figure is the same. They are referred to more fully in the text by the reference numbers.

connects with the trace of the echo from the bottom, yet the latter is plainly distinguishable, and there is no doubt about the character of the shoaler trace.

There is more doubt about a case such as is illustrated at (30) in figure 119. The trace of the bottom is distinguishable through the shoaler trace at (29) but it cannot be distinguished at (30).

Where the kelp is heavy enough to prevent any echo being received from the bottom, or where the trace from the kelp obscures any trace there may be from the bottom, the fathograms are useless unless supplemented by leadline soundings. In all such cases the fathogram should be carefully scanned for evidence of the true bottom, and where it cannot be seen, the areas should be investigated with the leadline.

A careful study of such fathograms will generally, but not always, show a difference between soundings on a true pinnacle and a reflection from kelp. Where the record appears as a Λ with open bottom, as described above, it can be interpreted as a true shoal. However, should the trace show a sudden shoaling with no indication of a Λ opening, it may or may not indicate an echo from kelp, and further investigation should be made.

*g. Evidence of strays.*—So-called strays may, at times, be difficult to distinguish from true shoals. In *A* in figure 117, there is no doubt about the nature of the mark at (2)—it cannot possibly be a shoal, although it can be, and probably is, an echo from some submerged debris, because close inspection of the record shows that the trace from the surface of the bottom is missing at this point. But if such a mark as at (2) comes at a depth where it resembles a shoal protruding from the bottom, one cannot always be certain of its true nature from the fathogram. For example, note that at (3) the trace of the bottom can be followed through the stray, but this cannot be done at (4), which may be a true shoal—at least there is no evidence that it is not. In *I* in figure 119 are similar examples. The detached traces to the right of (32) and the fainter mark to the right of (31) are without doubt strays. It is probable that (31) is a stray, from its characteristic shape, although the trace of the bottom cannot be followed through it. The other sharp uplifts look more like true shoals, although the level nature of the bottom seems to make this unlikely.

With reference to *e*, *f*, and *g* above, it cannot be assumed with assurance that a continuous record of the bottom through the base of a Λ-shaped shoal trace proves the nonexistence of a danger or obstruction. A fathogram record has been made over a known wreck and on this fathogram the continuous trace of the bottom is clearly evident, in addition to the shoaler record of depths on the wreck. In this case the recorded depths below the wreck are deeper than adjoining depths, which may be evidence of echoes from an angle from the periphery of the cone of sound. Theoretically, of course, it is possible, assuming a sufficient intensity of sound and gain control, to obtain a continuous record from adjoining depths while passing over a shoal, if the area of the shoal is less than the area of the cone of transmitted sound, where it meets the bottom.

Hydrographers should not expect the fathograms to be always self-explanatory. It is true that they contain a permanent record of much evidence that is lost when soundings are read from a visual instrument. But hydrographers must still investigate with vertical casts a sufficient number of representative places which cannot be surely interpreted from the fathograms alone. If the investigation of representative cases ensures a correct interpretation of all others of a similar nature, that should suffice; otherwise all doubtful places on the fathograms must be investigated with vertical casts.

It is important that the fathogram record be clear, that the fix marks and other events be legibly and neatly identified, and that a minimum of notations be made on the fathogram to ensure its correct interpretation. Figure 120 illustrates a fathogram with the notations properly made.

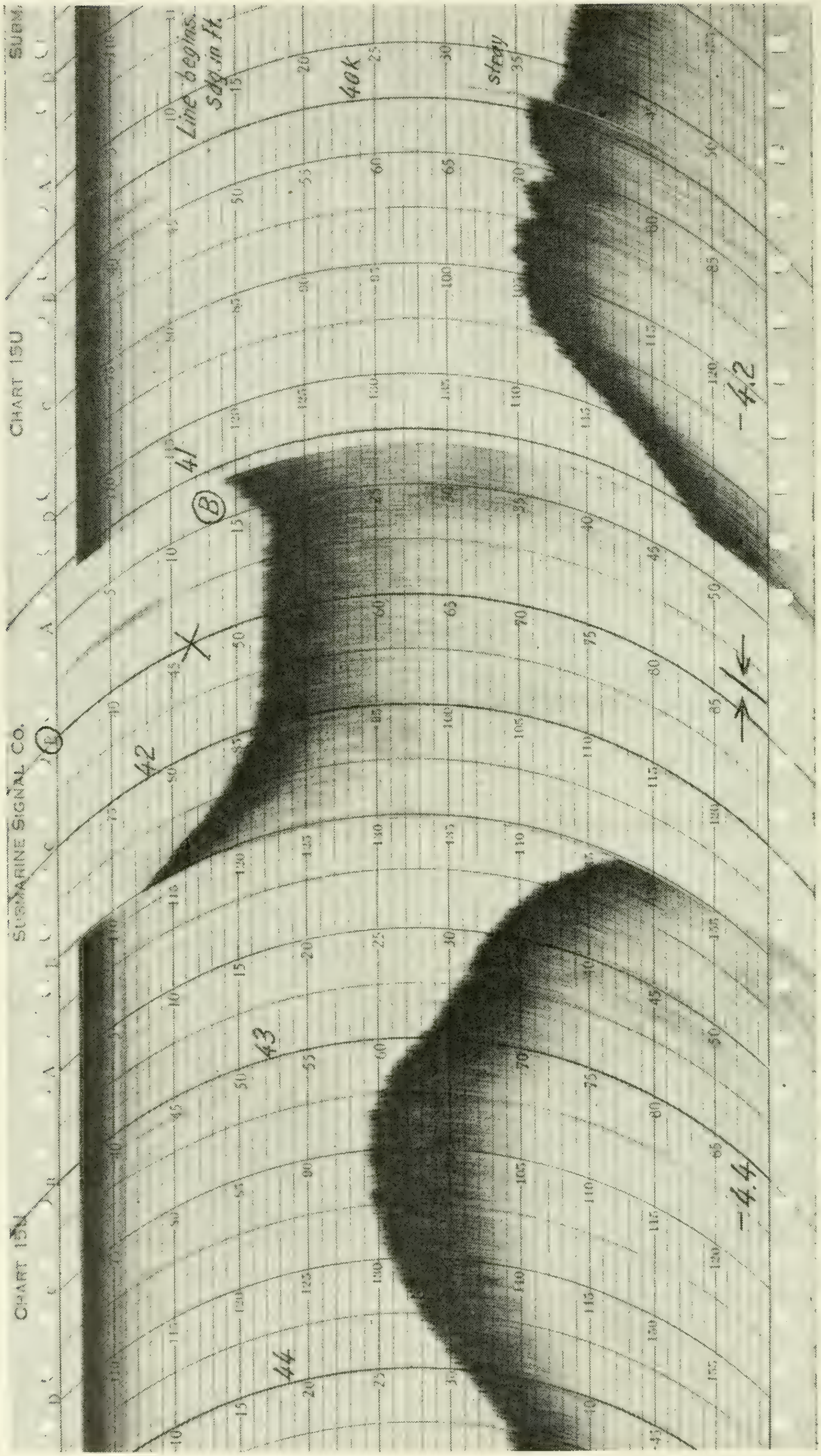


FIGURE 120.—Illustration of a fathogram on which notations have been properly made. (Where the phase used is other than the first (or *A*) phase, it should be indicated by encircling the correct letter every time it is repeated at the top of the fathogram. The tide need be entered at the bottom of the record only if the soundings are to be scaled mechanically.)

TABLE 21.—*Echo-sounding instrument operation*

| Nature of test or maintenance | Frequency | Instruments and reference numbers | | | | |
|---|---|---|---|---|---|---|
| | | 808 Fathometer | 312 Fathometer | Dorsey Fathometer No. 1 | Dorsey Fathometer No. 3 | Hughes Veslekari |
| Compare depth with Dorsey No. 3 | 3 times daily | | | | | 5544 |
| Bar check | do | 5617 | | | | |
| Change stylus | Twice daily | 5238b | | | | |
| Verify draft | Daily | 5513 | 5513 | 5513 | 5513 | 5513 |
| Verify setting of dog | do | | 5543 | | | |
| Charge batteries | do | 5235 | | | | X |
| Clean recorder cabinet | do | 5237b | | | | |
| Check motor speed | do | | | | | 5555 |
| Inspect and adjust stylus | do | | | | | X |
| Instrumental error | Weekly | | 552 | 552 | 552 | 5544 |
| Inspect and adjust governor brushes | do | | | | | X |
| Inspect water level in acoustic tanks | do | | X | | | X |
| Inspect and clean paper wick | Every 2 weeks | | | | | X |
| Inspect gear box and lubricate | Every 3 weeks | 5237a | | | | |
| Inspect governor and keying contacts | do | 5237b | | | | |
| Verify calibration of tachometer | Monthly | 5554 | 5553 | | | |
| Lubricate driving motor | do | 5237a | | | | |
| Clean magnetostrictive unit housing | do | 5237 | | | | |
| Verify tuning of echo amplifier | do | | | 5267(1) | 5267(1) | X |
| Inspect and adjust contacts | do | | | | | X |
| Lubricate all moving parts with recommended lubricants | do | | | | | X |
| Lubricate bearings of motor and dynamotors | Every 2 months | 5237b | | | | |
| Inspect brushes and commutators of motors and dynamotors | do | 5237b | | | | X |
| Change water in acoustic tanks | do | | | | | X |
| Lubricate prime mover and generator | do | | X | X | X | X |
| Measure settlement and squat | Once each season | X | X | X | X | X |
| Send tachometer to Office for calibration | Yearly | 5554 | 5553 | | | |
| Clean acoustic units and tanks and test insulation | do | | X | | | X |
| Verify frequency of tuning fork | do | | | 5551 | 5551 | |
| Lubricate indicator motor bearings | do | | | X | X | |
| Inspect transceiver or oscillator diaphragm and paint | do | | X | X | X | |

### 572. Instrument Tests and Maintenance

Throughout the text of chapter 5 various tests and the maintenance of the various instruments used by the Coast and Geodetic Survey have been described. For convenience these have been summarized in table 21 with reference numbers to the text where they are described more fully. The **X** entries in the table are just as important as the others although they may not have been particularly stressed in the text. Each entry is listed according to time and this is intended as a reminder to the hydrographer when each should be accomplished. It is not the intention of this table to prescribe the exact frequency of these operations. Experience with each instrument under varying conditions of operation may establish this better. However, it must be borne in mind that no departure should be made from the requirements of this schedule which will in any way result in less accurate soundings or endanger the instrument because of inadequate maintenance.

One blank column has been provided for similar entries for any new type of instrument acquired.

## 58. ECHO-SOUNDING EXPEDIENTS

When results cannot be obtained with echo-sounding instruments operated conventionally, either because the depths are beyond the effective range of the instrument or for other reasons, unconventional expedients can sometimes be used in emergencies to obtain results. The two described here are only typical and the inference should not be drawn that there are not others which will give equally good results. No such method should be utilized, however, except in an emergency.

### 581. Deep-Water Sounding With the 312 Fathometer

Where the depths are beyond the effective range of the 312 Fathometer, the index disk can be disengaged so that a signal of longer duration can be transmitted by making the necessary contact manually, as is done in adjusting the index (see **5543**). The echo from this longer transmitted signal can often be heard in earphones, when no results can be obtained by operating the instrument conventionally. The elapsed time between the transmitted signal and the reception of the echo must be accurately measured on a stop watch or chronograph. The transmitted signal will record automatically on the chronograph (see **5553**) but because the echo will be weak its reception will probably have to be recorded manually.

### 582. Sounding With Bombs

To sound in deep water, in the absence of a deep-water echo-sounding instrument, or in water whose depth exceeds the range of the available instrument, bombs can be substituted for the oscillator, and the R.A.R. chronograph (**673**) used as a time-measuring device. The time required for the sound of the bomb explosion to travel to the bottom and return is measured on the chronograph tape in seconds, as in standard R.A.R. practice (**685**), and after having been corrected it is multiplied by the mean velocity of sound from surface to bottom.

The bombs must be exploded at a known depth. This may be effected by attaching each bomb to an inflated paper bag by a cord of the desired length. Four fathoms is suggested as a proper depth. This involves no hazard since the paper bag soon becomes water-soaked and permits any unexploded bomb to sink. (See also **6846**.)

The operation otherwise is similar to that used in distance finding in R.A.R. The bomb explosion is received through the ship's hydrophone and recorded on the chronograph, the echo received later from the bottom being also recorded. The time intervals are scaled as in R.A.R. (**6853**), and the same "ship's run corrections" are added to the scaled values. A constant equal to the mean depth of the bomb explosion and the ship's acoustic receiving unit must be added to the final result.

Comparisons indicate that depths measured in this manner in about 2,000 fathoms are, on the average, less by some 15 fathoms than simultaneous depths measured by echo-sounding instruments. The data are inconclusive but seem to indicate that sounding with bombs should give results within the specified accuracy of 99.5 percent for depths of 3,000 fathoms or greater.

Sounding with bombs is authorized only for experimental purposes or in an emergency in deep water, when authorized methods fail to give results.

# CHAPTER 6. RADIO ACOUSTIC RANGING

## 61. GENERAL STATEMENT

Radio Acoustic Ranging (R.A.R.) is a method of control used in hydrographic surveys for determining the position of the survey vessel by indirect measurement of two or more distances. The distances are derived from the accurate measurement of the times required for a subaqueous sound, originating at the position to be determined, to reach two or more suitably located receiving units whose geographic positions are known. The distance from the source of sound to each receiving unit is determined by measuring this travel time and multiplying it by the effective velocity of sound. With two or more distances thus determined to receiving units suitably located, the position of the survey vessel is then located on the survey sheet at the intersection of arcs constructed with these distances as radii. R.A.R. is used in areas beyond the visibility of shore signals and where the use of survey buoys is not practicable or is unnecessary. It is independent of the conditions of visibility and, therefore, may be used at night or during times of reduced visibility.

### 611. History of Development

Subaqueous sound was first used in navigation to determine the direction of an underwater source of sound from a vessel equipped with two hydrophones (subaqueous sound receivers), one on each side of the vessel near the bow. A patent was granted for this device in 1894. The direction was found by varying the heading of the vessel until subaqueous sound of equal loudness was heard simultaneously in earphones, one connected to each hydrophone. Probably the first practical use of subaqueous sound to determine horizontal distances at sea was in connection with the use of the submarine bell as an aid to navigation during fog. Submarine bells, suspended 25 to 30 feet below a lightship, were in general use by the United States Lighthouse Service in 1906. The submerged bell was synchronized to strike simultaneously with the blast of a fog whistle in air, and from the interval of time between the reception of the subaqueous sound through the water and the reception of the fog whistle through the air a mariner could determine his distance from the lightship. A radio signal was successfully substituted for the whistle signal in experiments conducted in September 1911. The principle upon which those experiments were based is very similar to that utilized in R.A.R. by the Coast and Geodetic Survey, but the method was never extensively used in navigation because of the rapid development and use of radio direction finding.

It is interesting to note that the development of echo-sounding methods to measure depths of water resulted from an attempt to develop a method of measuring horizontal distances by subaqueous sound. Although much experimental work had been done previously (see **512**), it was the sinking of the *Titanic* in 1912 that emphasized the need for a method of determining the existence of icebergs in the track of a vessel and led to the improvement of instruments designed to produce and to detect subaqueous sound. These instruments, however, found their greatest application in measuring depths of water and future development was toward perfecting them for this purpose.

The submarine menace of World War I made urgent the development of a practical method of detection, which led to intensive study of the transmission of sound through sea water in an effort to solve the problem. An organization of the best scientists, working with the military services, added greatly to the knowledge of the subject. Instrumental equipment for, and methods of, transmitting and receiving subaqueous sound were perfected. Instruments for the specific purpose of measuring the time of transmission from source of sound to receiver were also developed.

After World War I, the United States War Department continued to study the transmission, reception, and velocity of sound, principally in the waters of Fishers Island Sound. Small bombs, suspended below targets whose positions could be determined, were exploded and the arrival of the sound wave was recorded at shore stations connected by cable to submerged hydrophones at various distances from the source. The results obtained encouraged the Coast and Geodetic Survey to try to modify the method so it could be used to control hydrographic surveys.

The first experimental work in the development of R.A.R. was performed in collaboration with the War Department in Fishers Island Sound in October and November 1923. The first time-measuring apparatus was based on the equipment developed by the United States Bureau of Standards for the longitude observations of the Coast and Geodetic Survey, modified for use on board ship. In the initial phase of the development, the Bureau of Standards collaborated in the design of the instrumental equipment, while the Coast and Geodetic Survey developed the practical technique of operation for use in hydrographic surveys. The apparatus was field-tested and the survey routine was developed on the Ship *Guide* off the coast of Southern California in February and March 1924, and by the end of March the method was in actual use, although improvements continued to be made.

## 612. Theory of R.A.R.

There are several general methods of sound ranging to determine the position of an unknown point:

(*a*) The arrival time of a sound signal may be observed at three or more time-coordinated receiving units at known positions. The differences of the arrival times at the various receiving units can be used to derive the position of the source. This is known as the differential method and is in general military use to determine the positions of enemy gun emplacements.

(*b*) The travel time of a sound, synchronized with a radio signal at the source, may be observed at two or more shore stations at known positions. The time interval measured at each shore station may be radioed to the survey vessel where the position of the source may be determined.

(*c*) A sound signal may originate at the vessel, where the time of its origin is recorded. The arrival times of the sound at two or more receiving stations are transmitted automatically by radio and received and recorded on board the vessel. The time required for the acoustic wave to travel to each receiving station may be scaled from the record and the position determined from these data.

The accuracy of these methods depends on the position accuracy of the receiving units, the accuracy with which the time intervals are measured, the accuracy with which the velocity of sound is known, and the diagnosis of the path along which the sound wave is propagated in reaching each receiving unit.

For most efficient use in hydrographic surveying, observations taken for the determination of the ship's position must be controlled on board and the observed data must be available in the shortest possible time after the observations. Because of these requirements the method outlined in (*c*) is the most practicable for use in R.A.R.

The subaqueous sound is made by exploding a small TNT bomb in the water near the survey vessel. This explosion is recorded on the vessel on a chronograph tape on

which time intervals are recorded. The sound of the explosion travels in all directions and on arrival actuates each receiving unit so that a radio signal is automatically transmitted. The several radio signals are recorded on the vessel on the same tape with the explosion. The travel times to the respective receiving units are scaled from the chronograph tape. These travel times are converted into distances by applying the effective velocity of sound in sea water and, if the positions of the receiving units are known and they are appropriately located, the position of the vessel may be determined from two or more of them.

### 613. Practical Use of R.A.R.

In other methods of horizontal control described in section **33**, the survey party must either have good visibility for the angle measurements required to locate the soundings accurately, or be satisfied with relatively poor locations based on dead reckoning, perhaps supplemented by astronomic sights.

Before the development of R.A.R. it had been generally accepted that soundings could not be located accurately in horizontal position during periods of low visibility, and in areas beyond the visibility of shore signals. Using R.A.R., accurate hydrographic surveys can now be conducted, regardless of the visibility, continuously day and night, and if combined with a system of buoy control (see section **25**), such surveys can be extended to a distance from shore that appears to be practically unlimited.

The accuracy of any method used to control hydrographic surveys limits its practical use. In R.A.R., instrumental equipment and field methods have been developed to where the time intervals can be very accurately measured. The velocity of sound, which must be known to compute the distances, is generally difficult to determine and this, combined with an inadequate knowledge of the character of the propagation path of the sound in the medium, usually limits the accuracy. The character of propagation may also limit the distance at which R.A.R. is effective, but if a sufficient number of receiving units are used and their sites are carefully selected, the method may be extended to control the hydrographic survey of any ocean area beyond the visible limits of shore signals.

## 62. PHYSICS OF SOUND

The Radio Acoustic Ranging (R.A.R.) method of controlling hydrographic surveys is dependent on the transmission of sound through sea water. The propagation of sound through air has been the subject of extensive studies in the past—but its propagation through water has been less extensively investigated, because of its comparatively limited application. The subject of sound transmission through water is treated in a general way in a number of publications, but complete information dealing specifically with the horizontal transmission of sound through water is not available in any one of them.

The recent extensive use of the R.A.R. method of control by the Coast and Geodetic Survey has disclosed the limited knowledge of the subject. A thorough investigation of it is difficult because of its complicated nature and would be costly because it would require elaborate instrumental equipment and observations from expensively operated vessels for long periods of time in order to investigate all of its ramifications. With the exception of a few planned experiments, all data on the subject particularly applicable to R.A.R. have been obtained during the survey operations of the Bureau in various offshore localities. A knowledge of it has little practical application except in sub-

aqueous sound ranging and detection, but in these respects a thorough understanding of the subject is of primary importance.

For the most successful use of R.A.R., not only are experimental investigations essential but the physical laws governing the propagation of sound should be understood. These physical laws are therefore briefly reviewed in **621**. The propagation of sound through an ideal water medium of homogeneous physical properties is discussed in **622**, for the physical laws of sound can thus be more easily illustrated and more clearly understood. Such a medium is not necessarily hypothetical, for such conditions are occasionally approached in actual practice. In **623** is considered propagation through water whose physical characteristics are of a heterogeneous nature, more nearly approaching the actual conditions most frequently encountered in subaqueous sound ranging. The treatment is often necessarily from a theoretical viewpoint when the actual facts have not been fully disclosed by experimental investigations.

In R.A.R. explosive sources of sound are used in order to permit detection at great distances. Most of the energy from such explosions is in the low frequency range and it is sounds of such frequency that are here considered. Sounds of higher frequency having other underwater applications may follow different modes of propagation.

## 621. Physical Laws of Sound

Sound is a form of energy transmitted through an acoustic medium by virtue of the elastic properties of the medium. Acoustic energy is transmitted through an elastic medium by being passed from one particle to another in the direction of propagation. When a sound passes through a medium, the particles in the medium at any given point along the path undergo a minute, purely local, longitudinal displacement. This local particle motion must be clearly distinguished from the longitudinal wave motion, which is the forward travel of the sound energy from particle to particle through the medium.

The particles in a medium through which a sound wave is passing are represented by vertical lines at the top of figure 121. At $A$ and $C$, where the lines are spaced most closely, maximum instantaneous pressure of the medium is represented—the particles or molecules are grouped more closely than in the undisturbed medium, and the medium is said to be *condensed*. At $B$, where the vertical lines are farthest apart, minimum instantaneous pressure of the medium exists—the particles or molecules are grouped farther apart than in the undisturbed medium and the medium is said to be in a state of *rarefaction*. At these points of condensation and rarefaction as the wave travels forward, the pressure is increased and decreased above and below the normal pressure of the undisturbed medium. Where the wave form is sinusoidal, as illustrated, these points of maximum condensation and rarefaction are always separated from each other by one-half the wave length, and they move forward with a constant velocity in a homogeneous medium. The velocity of the forward travel is a function of the elasticity and density of the medium (see **63**).

Sound waves are defined by certain characteristics of the disturbing force and of the medium. These characteristics, some of which are interrelated, are: phase, frequency, wave length, and intensity. The **phase** of a sound wave at any instant and at any given point is based on the position of the particle relative to some reference such as its maximum displacement. Thus in figure 121, $A$ and $C$ are in the same phase. The **frequency** depends on the sound producing source; for example, if the source is

vibrating 150 times per second, the frequency of the sound wave produced will be 150 cycles per second. The **wave length** is the distance between particles in the same phase. It is determined by the ratio of the wave velocity ($v$) to the frequency ($f$); for example, if the velocity of sound is 1,500 meters per second and if the frequency is 150 cycles per second, the wave length is 10 meters. The **intensity** of a sound wave is defined as the energy (the capacity to do work) transmitted through a unit area in a unit of time. Intensity is usually measured in terms of energy, in ergs transmitted per second through 1 square centimeter of surface perpendicular to the forward motion. The intensity of sound must not be confused with *loudness*, because intensity is purely

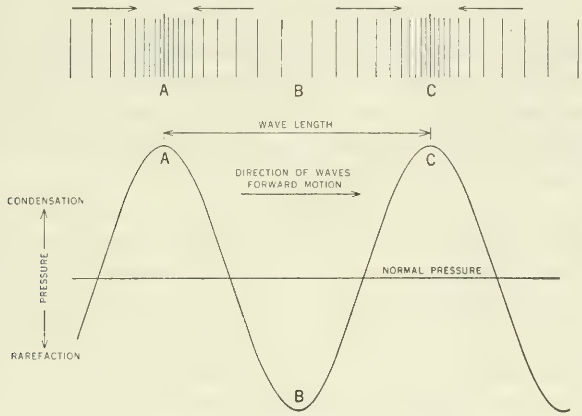


FIGURE 121.—Sinusoidal sound wave.

a rate-of-energy term, while loudness depends on frequency as well as intensity. Unless the sound is of a frequency perceptible to the human ear, it is not loud, although its intensity may be great.

A sound wave transmitted through an elastic medium will travel in a straight path until it encounters a change in physical characteristics of the medium, where its direction will be changed by either reflection, refraction, diffraction, or a combination of these. At any point in a medium where sounds of identical frequency and wave form arrive from different directions there will be interference. This may result in a decrease or an increase in intensity at this point between the limits of zero and the sum of their intensities, depending on the relation of the phases and the values of the intensities of the two waves.

When a sound is transmitted through a medium from one point to another its energy is attenuated. In practice this attenuation is due to the summation of all acoustic energy losses which take place. The failure of part of the sound energy generated at the source to reach the reception point may be due to transmission of energy to points other than that of reception, and due to the conversion of acoustic energy into heat. Some of the generated acoustic energy may fail to reach the point of reception because of lack of directivity of the source; simple refraction, reflection, diffraction, and interference; and diffuse refraction and reflection. In any case some of the acoustic energy will be lost during transmission because of the viscosity of the medium. The amount of energy reaching the point of reception will be decreased by turbulence, aeration, and suspension of foreign matter.

For long-distance transmission of sound, water is probably the best medium. It has homogeneous physical properties which are relatively stable as compared with

other media. Sound waves in water are confined to a layer between definite boundaries formed by the surface and the bottom, a condition not found in other media of large dimensions. This layer is of varying thickness, but its vertical dimension is generally small as compared to the horizontal distances usually involved in subaqueous sound ranging.

## 622. Propagation in an Ideal Water Medium

The laws governing the propagation of sound in water can be more clearly explained and understood if the transmitting medium is assumed to be a homogeneous one and if the boundaries are well defined, plane, and parallel. Furthermore, in a simple case of this nature, and assuming the frequency of the sound is low enough not to be attenuated by the viscosity of the medium, efficient transmission of sound will be obtained. A body of water approaches the ideal case of homogeneity where the temperature and salinity are uniform throughout, and where foreign matter is absent. And, under these conditions, it will afford efficient transmission of sound if the bottom is smooth and level, and presents a good reflecting surface.

Such a condition is not entirely hypothetical for, during certain seasons, this ideal is approached in certain localities; for example, in certain areas of nearly uniform depth on the Atlantic Continental Shelf during the winter and early spring. In some localities on the Pacific Coast and in Alaska waters, conditions approach this ideal during most of the year. (See fig. 130.)

From a nondirective source of sound in an elastic medium, waves are radiated in all directions. From the source to the point of reception in a bounded medium a sound wave may travel an almost unlimited number of paths. There may be a direct path, a refracted path, and a multitude of reflected paths. In practice it will be found that all three of these types of paths apply to subaqueous sound ranging in varying degrees, depending on the distance and the condition of the medium. Within a certain range the sound that travels along the direct path (without reflection from the boundaries) will be the first to reach the receiving apparatus, but at a greater distance, where an unreflected wave cannot reach the point of reception, sounds that have been refracted and reflected will be the only ones to arrive. The sound wave that arrives first with sufficient intensity to be detected is, of course, the one that is used in subaqueous sound ranging—any sounds arriving later only serve to prolong the received signal. In **6221** and **6222** which follow, the propagation by various paths is considered.

### *6221. Reflection of Sound*

The long-distance transmission of sound in water is greatly assisted by reflections. Subaqueous sounds, after having been reflected a number of times, are known to have retained sufficient energy to be recorded at a distance of 400 nautical miles from the source by instruments of only ordinary sensitivity. And a sound wave generated by an electromagnetic oscillator to measure the depth in about 200 fathoms of water has retained sufficient energy to be heard in headphones after having been reflected 23 times alternately from the bottom and the surface. The excellent transmission of sound in water is due, not only to the fact that water is a relatively good medium for the propagation of sound waves, but also to the relatively good reflecting surfaces formed by the water surface and bottom. The boundary between air and water, when the latter is smooth, is a good reflecting surface for sound waves; likewise the boundary between

the water and bottom, where composed of certain materials, offers a surface from which most of the energy of the sound wave will be reflected.

The laws governing the reflection of a sound wave in water are the same as the laws that govern reflections in any other medium. When a sound wave meets a reflecting surface its direction of propagation is changed. For example in *A*, figure 122, the incident ray of the sound wave meets the reflecting surface at *a* and is reflected in the direction of the dash line. The direction after reflection depends on the angle of incidence *i* between the incident path and the normal *an* to the reflecting surface. The path of the reflected wave will always be inclined to this normal at an angle of reflection *r*, which is always equal to the angle of incidence.

Each point in the sound wave *W* from a source *S* (see *B* in fig. 122) will be reflected from the reflecting surface as the wave advances. As successive points between $a_1$ and $b_1$ in the incident wave *W* reach the reflecting surface between points *a* and *b*, the direction of propagation of the wave will be changed, and the reflected wave *WR* may be considered to be the resultant of a number of hemispheric wavelets between

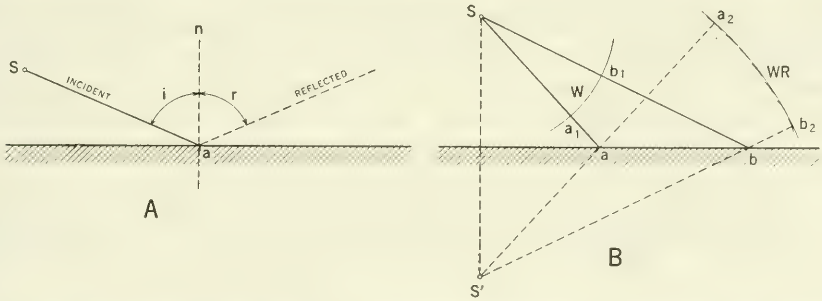


FIGURE 122.—Sound reflected from a rigid surface—*A*. Change of direction of path. *B*. Wave front retained after reflection.

$a_2$ and $b_2$, whose sources lie on the reflecting surface between *a* and *b*. This is known as Huygens' construction for reflected waves.

The source of the reflected wave may be considered to be at point *S′*, the acoustic image of the source, symmetrically located on the opposite side of the reflecting surface with reference to the source. By considering the reflected wave to be propagated from the image source, the phenomenon of reflection may be more readily visualized. Where reflection is due to a medium of greater radiation resistance the source and its image are to be considered as in phase, but where reflection is due to a medium of lesser radiation resistance the converse is true. Radiation resistance is the product of the density of the medium and the velocity of sound in the medium. The radiation resistance, or acoustic resistance, of air is less than that of water, and that of water is less than that of the ocean bottom.

Where a sound wave is reflected from a surface, a change of phase of pressure or a change of phase of particle velocity occurs. Assuming a sound source in water, if the reflecting surface is that of a denser medium, as at the bottom boundary, the change will be in the phase of particle velocity; but if the reflecting surface is that of a less dense medium, as it is between water and air, the change which occurs will be in the phase of pressure. In each case there will be a phase reversal.

The relative amount of acoustic energy that will be reflected where a sound wave meets the bounding surface of a second medium, is a function of the angle of incidence and the radiation resistance of the two media. This function is such that, in the case

of any two given media, for different angles of incidence different relative amounts of energy will be reflected, with one exception. The exception to this is found in the specific instance of a source located in the medium of lesser sound velocity and where the angle of incidence is equal to or greater than the critical angle. In this case total reflection will take place. The critical angle of incidence of a sound wave is defined as the angle, measured from the normal to the interface or bounding surface, whose sine is equal to the ratio of velocity in the medium containing the source to the velocity in the reflecting material, or medium.

Therefore where the reflecting medium is air and the transmitting medium is water there is no critical angle because in this case the ratio of velocities is greater than unity. But where reflections from the ocean bottom are considered there will be a critical angle. Where the angle of incidence is equal to or greater than this critical value there will be total reflection, and where the incident angle is less than this critical

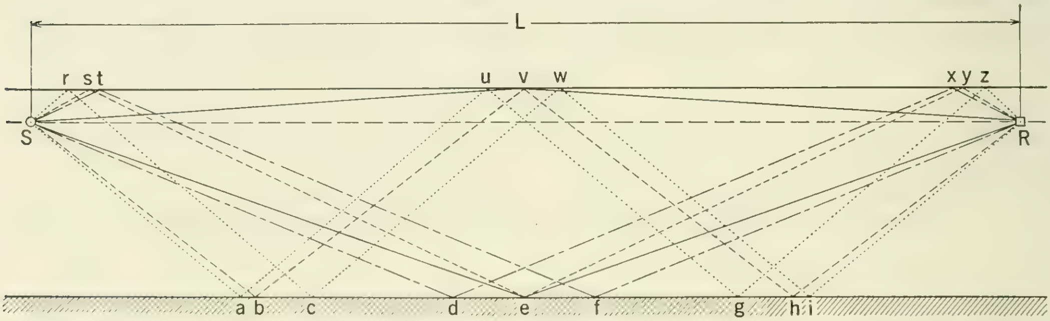


FIGURE 123.—Multiple reflections in a bounded medium.

value the reflection will be only partial. The critical angle of reflection from a bottom of solid rock is about 17° but for other materials it may be as large as 70°.

Hence in subaqueous sound ranging the critical angle will be approached only where the horizontal distance between the source and the point of reception is less than six times the depth of water (assuming the ocean bottom as flat and a critical angle of 70°) and, therefore, total reflection from the bottom will occur at this and greater distances. Furthermore, although theoretically total reflection will never occur at any angle at the surface of the water, practically the amount of energy that is transmitted into the air will be negligible due to the great disparity in the two radiation resistances. Thus in practice total reflection may be *assumed* at both surfaces in nearly every case.

From the source to a point of reception, sound may be considered theoretically to travel along a number of reflected paths, one series which is first reflected from the surface, and another series which is first reflected from the bottom, as in figure 123, where, for clarity, only four of the paths reflected from each of the surfaces are illustrated.

The first reflected sound that reaches the point of reception, where the source and the point of reception are near the surface of the water, will have been reflected from the surface at the point $v$, while the first sound reflected from the bottom to reach the point of reception will be from point $e$. The second surface-reflected ray to be received is reflected from the surface at point $t$ and from the bottom at point $f$, while the second bottom-reflected ray is reflected from the bottom at point $d$ and from the surface at point $x$. With a greater number of reflections the points of first reflections from the surface and the bottom will be closer to the source.

For subaqueous sound ranging in very shoal water, where the ratio of the horizontal distance to depth is 200 to 1, or greater, the actual lengths of the sound paths, where few reflections are involved, differ very little from the respective horizontal distances. Figure 123 is deceptive in this respect because the vertical scale is greatly enlarged and does not show the true relation of depth to distance that exists in practice. In a depth of 50 fathoms for a distance of 10 nautical miles, the path of a sound wave that has been reflected 12 times is only 33 meters longer than the horizontal distance. For a greater depth and longer distance, the difference will, of course, be larger—for example, where the depth is 1,000 fathoms and the distance is 50 miles, the theoretical difference between the path of a sound wave reflected 12 times and the true horizontal distance is 2,550 meters.

### *6222. Refraction of Sound*

Any change which may occur in the direction of propagation of a sound wave is obviously of primary importance in subaqueous sound ranging. A change of sufficient magnitude in the direction makes the simple laws of reflection inapplicable, for if the direction of propagation is changed sufficiently in a vertical plane toward the point of reception, the number of reflections is altered, thus increasing or decreasing the length of the reflected path. Unfortunately such a change in the direction of propagation of sound does take place in all water media. This is known as refraction. Refraction of sound makes any analytical study of the propagation of sound more difficult. Also it is doubtless responsible for many of the difficulties that are experienced in subaqueous sound ranging and hence a thorough understanding of its laws is necessary.

The change in direction of a sound wave caused by refraction is shown in figure 124. Where any part, as $a_1$, of the incident wave $W_1$ in the first medium encounters the boundary between media at point $a$, it will be refracted from this point as a secondary source, or origin, at a different velocity. Succeeding points in the incident wave will be refracted later at corresponding points along the boundary until the entire wave penetrates the boundary and the refracted wave $W_2$ is formed. It is evident from the figure that the wave in the second medium will travel at a different angle owing to the fact that the velocity in this medium is different. All the energy is transmitted through the boundary only when the acoustic resistances of the two media are equal and the angle of incidence is normal to the boundary. Where the acoustic resistances of the two media are different, a varying amount of the energy will be reflected depending on the difference in acoustic resistances and the angle of incidence. Where the angle of incidence is greater than the critical angle, regardless of the relation of the acoustic resistances, no transmission into the second medium takes place, and all of the incident energy at this angle and greater is reflected (see **6221**).

Refraction occurs wherever a sound wave encounters either a boundary between media in which the velocities of sound are different, or in a medium in which the velocity of sound is continuously changing. If a sound wave in transmission encounters a boundary between media in which the velocities of sound differ, the direction of propagation will be changed. If the velocity of sound in the first medium is greater than it is in the second medium the direction of propagation will be changed away from the boundary between the media, as in figure 124, but if conditions are reversed and the velocity in the first medium is less than in the second, the change in the direction of propagation will be toward the boundary. The angular change in the direction of propagation may be found from the formula given with figure 124, in which $i_1$ is the angle of incidence in the first medium and $i_2$ is the angle of refraction in the second

medium, and $v_1$ and $v_2$ are the values of the velocity of sound in the first and second medium, respectively.

As explained in **6221**, when a sound wave in water encounters the surface boundary, only a very small percentage of the incident energy is transmitted through the boundary into the air. This is because the difference between the acoustic resistances of air and water is very large—the ratio being 1 : 3,750. Even at normal incidence only about 0.12 percent of the incident energy will be transmitted into the atmosphere. This fact is substantiated in subaqueous sound ranging, for bomb explosions below the surface cannot be heard on board ship, but vibrations from the explosions are transmitted through the water and can be felt through the hull of the ship. This also accounts for the fact that the sound of the propeller of a ship is not heard above the surface.

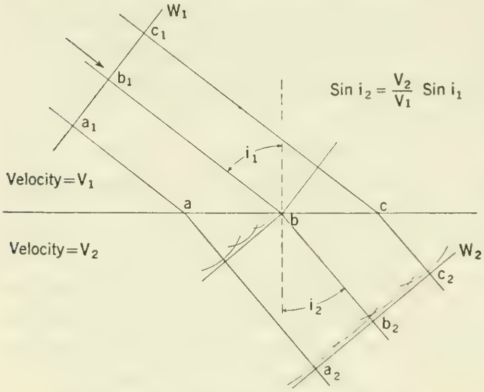

FIGURE 124.—Total refraction of a sound wave.

There is generally no transmission through the bottom boundary at the angle of incidence of a sound wave that is normally encountered in subaqueous sound ranging. Normally the angle of incidence is greater than the critical angle and hence total reflection occurs. The change in the direction of propagation caused by refraction due to the pressure gradient, as explained below, increases the angle of incidence of the effective path slightly.

In an ideal water medium the velocity of sound would increase linearly from surface to bottom because of the linear increase in hydrostatic pressure. This is sufficient to increase the velocity 1 meter per second for every 30 fathoms increase in depth. This constant increase in velocity causes the sound wave to be refracted in the arc of a circle, concave upward. The maximum distance that a refracted sound wave can travel without reflection in a fluid medium of uniform temperature, is determined by the refracted path that is tangent to the bottom. This is also the shortest path, for any other part of the sound wave will be reflected from either the surface or the bottom between the same source and point of reception, and hence in either case will have traveled a greater distance, arriving later than the part that followed the tangentially refracted path.

Therefore, for distances shorter than the limit determined by the tangentially refracted ray, the first sound to arrive will not have been reflected at all; but for distances beyond this limit, the refracted sound which is reflected one or more times from the upper surface only will precede all others.

However, at a considerable distance from the source, unreflected sounds and sounds which are reflected only from the water surface, will be of reduced intensity due to the interference phenomenon (**6223**). Because of this, and because in practice the sensitivity of the receiving system is necessarily limited by the background noises, the first sound to be *detected* may not be that which actually arrives first.

### *6223. Interference of Sound*

Although a single source of sound is used in subaqueous sound ranging, reflections from the surface and bottom cause propagations in the medium in various directions

from image sources as explained in **6221**. These reflected paths, which are reversed in either phase of pressure or phase of particle velocity according to the character and number of reflecting surfaces they encounter, cross the direct path and each other in the medium, and at their points of intersection the pressure or particle velocity is either reinforced or neutralized by an amount depending on the phase relationship of the waves. This has already been mentioned briefly in **6221**, but because of its importance in subaqueous sound ranging a fuller discussion of the effect is desirable.

If two waves of the same amplitude and wave length arrive from different directions and meet in condensation, the amplitude at this point will be increased, but if they intersect when one is in condensation and the other in rarefaction they will tend to neutralize at this point. In neither case will there be energy transfer or loss, however, and each wave will emerge in its original direction of propagation and with its original amplitude. In a water medium with a nondirective source of sound, there will be a number of zones of reinforcement and neutralization of both pressure and particle velocity, which are complicated by refraction.

The most important zone of interference occurs between the sound that travels directly from the source to the point of reception, and the sound that is reflected once from the surface of the water. This surface-reflected sound is reversed in phase and thus, at a distance from the source where the lengths of the direct and reflected paths are nearly equal, the pressure and particle velocity are nearly canceled. This effect limits the range of both the unreflected and the surface-reflected sound, and is the reason why, in actual practice in subaqueous sound ranging, the maximum distance at which the unreflected sound is effective does not exceed 7 to 10 miles.

### *6224. Reduction of Sound Energy*

As sound passes through a medium, its intensity decreases as the distance from the source increases. This decrease in energy in a homogeneous medium, as discussed in **622**, may be attributed to absorption, reflection, refraction, diffraction, interference, and spreading.

Absorption is the conversion of sound energy to other forms of energy because of the presence of foreign matter in suspension in the medium, turbulence and viscosity of the medium, and thermal conductivity of the medium. Attenuation caused by viscosity may be considered as a loss of energy due to the resistance offered by the medium to the passage of sound. In a water medium and at the frequencies effective in subaqueous sound ranging, viscosity losses are very small in comparison with other losses. Thermal conductivity of the medium allows the conduction of heat from the condensed points of the wave, which are at a higher temperature than the surrounding medium. These losses are very small in water, being even less than those caused by viscosity.

When the sound wave encounters the reflecting boundaries of a body of water, some of the sound energy will penetrate into the media above and below and thus be lost from the water medium. The transmission of energy through the surface boundary into the air above is very slight, as stated in **6222**. And transmission through the bottom boundary takes place only when the angle of incidence is less than the critical angle. The amount of energy penetrating the lower medium is a function of the angle of incidence and the acoustic resistances of the water and bottom material.

In a homogeneous medium, ignoring absorption, the intensity of sound from a point source varies inversely with the square of the distance from the source. Sound emitted

from a point source will therefore travel with equal intensity in all directions in a homogeneous medium. The wave front is a spherical surface of continuously increasing area, in which the intensity of the sound varies inversely with the increase in surface area of the sphere. This diminution of energy per unit of area of wave front is said to be due to spreading. In a bounded medium a sound wave will not travel far before its spherical wave front encounters the boundaries of the medium and is reflected, or before the direction of propagation is changed by refraction. However, even after reflection and refraction the intensity still varies inversely with the square of the distance of travel from the assumed point source.

### 623. Propagation in a Heterogeneous Water Medium

The propagation of sound in an ideal medium with uniform physical characteristics as discussed in **622**, is sometimes encountered in subaqueous sound ranging but, unfortunately, the medium is usually heterogeneous in most ocean areas, with some of the physical characteristics of the water medium varying in the distances through which sound must be transmitted. In such a water medium with constantly changing physical characteristics, the propagation of sound is indeed complicated.

In a water medium with a heterogeneous temperature condition, such that the temperature varies from place to place and from surface to bottom, the velocity of sound will be similarly nonuniform (see **632** and table 32 in **9611**). This variation of velocity with temperature causes the path of the refracted sound wave to be different from the path in a homogeneous medium, adding greater complexity to the nature of propagation. The attenuation of sound due to viscosity differs only slightly, however, at different temperatures—it is slightly less at a high temperature than at a low temperature because warm water is slightly less viscous than colder water.

Moreover, a variation of salinity in the water medium, either from place to place or at different depths, causes a slight change in the velocity. With an increase in salinity of 1 part in 1,000 parts of water, by weight, the velocity increases only 1.3 meters per second on the average, the increase varying slightly with the average temperature of the medium. Normally this change in velocity is so small that it causes only a slight refraction of sound as compared to the refraction caused by the change in velocity due to temperature. (See **63**.) An increase in salinity increases the density of a water medium and because of the increased density and the consequent increase in velocity due to density, there is a very slight decrease in attenuation.

All sea water contains some suspended materials, but only where large rivers discharge into the sea is the amount of suspended material enough to affect the velocity of sound, and then only slightly. But the attenuation factor is increased in proportion to the amount of foreign matter in suspension.

Most sea water contains various proportions of dissolved gases caused by aeration and the photosynthesis of marine organisms. Gas, if present in suspension in sufficient quantity, reduces the normal velocity of sound by a large amount. It has been stated that if the proportion is only 1 part in 10,000 parts of water by volume the velocity will be reduced 40 percent. This reduction of velocity will cause greatly increased refraction of sound and will also cause reflections within the medium. In addition, aeration causes increased attenuation because of conversion of acoustic energy into heat and because of diffuse reflection and refraction.

Small variations in the average depth of water apparently have very little effect on the propagation of sound, but if the source of sound is located in deep water and the

point of reception in shoal water, or vice versa, the propagation is complicated. Shoal areas and irregular bottom relief are the causes of regions of sound shadows, thus adding to the difficulties of Radio Acoustic Ranging.

Where the surface of the water is turbulent, reflections from this boundary will be diffuse and scattered, resulting in a limited range of transmission. The character of the bottom material also has a pronounced effect on the reflection losses at this boundary for, if the velocity of sound in the bottom material is nearly equal to the velocity of sound in water, part of the energy of the sound wave will be refracted into the bottom.

It is apparent that the propagation of sound in a heterogeneous medium is complicated by many factors, each of which may be different for each distance measured in subaqueous sound ranging. Some of these factors vary diurnally, seasonally, and regionally. Because of these complications the text of **6231** to **6233** is mainly restricted to typical conditions likely to be encountered in the various seasons and localities where subaqueous sound ranging is used by the Coast and Geodetic Survey.

### *6231. Reflection of Sound*

Reflection and refraction are equally important in the propagation of sound through sea water. Except for comparatively short distances, where the transmitted sound is affected by refraction only, propagation is by a combination of refraction and reflections. Refraction affects the length and direction of the sound paths in the medium, while reflection causes an abrupt change of direction at the boundaries of the medium.

First, consider the case of shoal water with the velocity of sound decreasing from surface to bottom in a fairly regular gradient. Except for very short distances from the sound source, the sound arriving at the point of reception will be by way of a number of reflections from the bottom and surface. The path between each reflection point will be concave downward because of refraction. (See **6232**.) The steeper the velocity gradient the greater will be the curvature due to refraction between reflections. For the accuracy required in R.A.R., refraction between points of reflection cannot be ignored. In other words, in computations of distance it cannot be assumed that the path of sound is composed of a number of straight lines between reflection points. And, the greater the refraction, the greater the number of reflections required for sound propagation over great distances. These conditions of refraction and reflection in depths less than about 50 fathoms are common in waters along the Atlantic Coast and in the Gulf of Mexico. Where the velocity gradient is not uniform the shape of the refracted path must be modified as explained in **6232**. This consequently changes the number of reflections a sound wave will undergo in traveling a given distance.

In general, a sound wave will undergo fewer reflections in traveling a given distance in deep water than in shoal water. This, in part, accounts for the greater distance ranges possible in deep water since less sound energy will be lost because of fewer reflections. Refraction in deep water is mainly due to the influence of hydrostatic pressure, since the change in velocity due to temperature ceases to be appreciable below about 200 fathoms. This condition exists in deep water off the Atlantic Coast and in the Gulf of Mexico and is the usual condition found along the Pacific Coast and in Alaska waters. (See fig. 130.)

The slope of the bottom reflecting surface plays an important part in determining the number of reflections between the source and point of reception. If the source of sound is where the water is deep and the point of reception is in shoal water, assuming a

bottom of uniform slope, a greater number of reflections will be required than in the case of a uniform depth equal to the average depth at these two points; if the source and point of reception were interchanged, fewer reflections would occur. Where the bottom slope is comparatively steep and the source of sound is where the water is deep, the sound may never reach a distant point of reception up the slope. For each successive bottom reflection the angle of incidence is decreased by an amount equal to the angle the bottom slope makes with the horizontal. After a number of surface and bottom reflections have taken place the path of sound may reach normal incidence, and on succeeding reflections may actually reverse its horizontal direction of propagation and return toward the source. Furthermore, before normal incidence is reached by successive reflections, the angle of incidence becomes less than the critical value, and appreciable transmission of energy into the bottom may take place in successively greater amounts, resulting in great attenuation of sound energy, particularly in the case of an extended gradual slope. This condition is even more aggravated in shoal water where more reflections will take place in a given distance than will in deep water. This partly explains the difficulty in sound transmission over shoals, and from deep water on the Continental Slope to shoal water on the Shelf.

Little of a practical quantitative nature is known about the influence of the bottom configuration and material on the reflection of sound. What is known has been deduced principally from observations made while surveying by R.A.R. Even these results are obscured by other influences on sound transmission to an extent which makes it difficult to interpret the degree of influence which the bottom configuration and material have. However, certain facts have been fairly well established from years of observation. Where the bottom is smooth the material has little influence on sound transmission, as used for purposes of distance measurement. This implies that the angle of incidence, in practice, is nearly always equal to, or greater than, the critical angle (see **6221** and **6222**). Where the bottom is irregular the distance at which subaqueous sound ranging is effective is very much reduced from what could normally be expected with smooth regular bottom. Sound reflected from such a bottom is scattered in many directions and the amount of sound energy which travels in a general radial direction from the source is very much reduced with each reflection. Such irregular bottom surfaces are common off the Pacific Coast, in the waters surrounding Alaska, and along the edges of the Atlantic Continental Shelf.

In general, reflections from the water surface are more definite than bottom reflections. The reflection coefficient between water and air is constant, the only variable being the degree of roughness of the water surface. Except when the water surface is extremely disturbed, there is little effect on the reflection of sounds produced by subaqueous explosions. This is because of the predominant low-frequency fundamental component of the subaqueous explosion. The wave length of this low-frequency fundamental component is long as compared to the size of the irregularities of the water surface (see **621**).

### *6232. Refraction of Sound*

In a heterogeneous aqueous medium the propagation of a sound wave is influenced principally by the temperature distribution within the medium and, to a lesser extent, by changes in salinity and other physical characteristics which cause a change in velocity. Where velocity varies with depth in the medium, refraction takes place and the path of the sound wave is altered from normal linear propagation. Due to this fact, the maximum effective distance in subaqueous sound ranging is reduced, because of

the increased number of reflections. Because temperature is the predominant characteristic determining the velocity, it is also the principal factor in determining the amount of refraction.

Thus, if the temperature gradient from surface to bottom is linear and the temperature near the surface is appreciably warmer, the sound is refracted so that its path is concave downward. The path marked $A$ in figure 125 illustrates this condition. The amount of curvature of the path due to refraction depends on the velocity gradient in the medium—the steeper the velocity gradient the greater the curvature of the path. Similarly the length of the longest unreflected path is determined by the magnitude of the velocity gradient and the depth. The sound that arrives first at a point of reception at a greater distance than this maximum range of an unreflected sound, arrives only after one or more reflections from the bottom boundary, depending on the distance.

Where the temperature at the surface is appreciably lower than the temperature at the bottom and the temperature gradient from surface to bottom is linear, a sound will be refracted so that its path forms a circular arc which is concave upward as illustrated by the path marked $B$ in figure 125. This is the same type of refraction that results in an ideal fluid medium when the change in velocity is due to pressue alone (see **6222**), but in this case the range of sound before reflection from the surface is reduced because the refraction due to the two causes is additive. The length of the

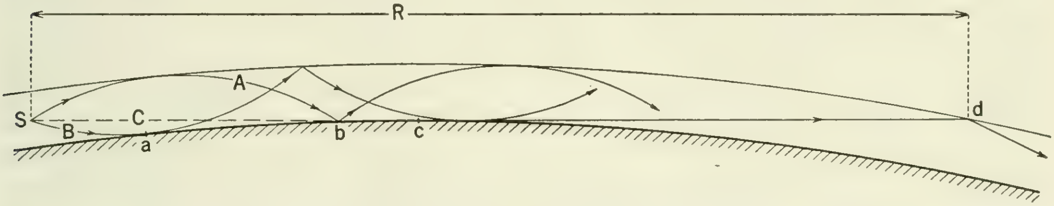


FIGURE 125.—Transmission of sound over great distances.

unreflected path is short where the vertical change in velocity is great and the depths are shoal, and it is long where the vertical change in velocity is slight and the depths are great. The first sound wave to reach a point of reception beyond the range of the direct path, will be reflected one or more times from the surface, depending on the distance.

In a medium having a temperature distribution from surface to bottom such that the velocity is linearly reduced by an amount just sufficient to neutralize the increase in velocity due to increased pressure, the velocity will be uniform throughout. Such a medium would be ideal for the transmission of sound and a maximum range of the direct unreflected path would be obtained. The range of the direct path would be limited, then, only by the curvature of the earth, and in the same way that the distance of visibility of objects at sea is limited. The maximum distance of unreflected propagation would be obtained where the linear path is tangent to the bottom, as illustrated by the path marked $C$ in figure 125. In this ideal case, with the source at $S$, the sound would be propagated linearly to any point in the volume bounded by the surface and the tangent plane represented by the line from $c$ to $d$. The formula,

$$R=1.15\ (\sqrt{D-d}+\sqrt{D-d'})$$

may be used to compute the maximum range $R$ (in nautical miles) of the direct path, given the depths (in feet) of the water $D$, of the source $d$, and of the point of reception $d'$.

The maximum range of this direct linear path may also be obtained from Table 8 the American Practical Navigator (Bowditch). The required distance is the sum of

two values from the table—the nautical miles for heights corresponding to $D-d$ and $D-d'$, assuming a uniform depth of water throughout the range. It should be noted that the distance along the direct linear path will be slightly shorter than the distance measured on the earth's surface, but for such distances as are involved in subaqueous sound ranging this difference is quite small and may be ignored.

However, it should be noted further that this ideal case of uniform velocity will never be approached closely enough in practice to warrant consideration of this maximum range of unreflected linear propagation from any other point of view than that of illustration. Moreover, interference (see **6223**) will reduce the intensity of a direct, linearly propagated sound to such an extent that it could not be detected at such a great distance from the source, in practice.

If a graph is made by plotting velocity with reference to depth, for use in subaqueous sound ranging, the shapes of the curves for most regions of the ocean will be quite similar. In general, the velocity will be relatively high at or near the surface and will decrease with depth to about 200 or 300 fathoms where the velocity will start to increase due to pressure and will continue to increase nearly linearly to the bottom. The relatively high velocity near the surface is due to atmospheric surface warming of the water. Sound originating from a point source near the surface in water with such a velocity gradient, will follow a path which is concave downward until it reaches a depth corresponding to that where the velocity starts to increase, and below that depth the path of the wave is concave upward. If the vertical velocity gradient in a body of water is uniform over a large area, the shape of the path of sound will be symmetrical with reference to the midpoint between the sound source and where it again reaches a depth equal to the source depth. If the velocity changes linearly with depth, but at different rates in different depth layers, the path of the sound wave will be composed of arcs of circles of different radii, a different arc for each layer. The radius of curvature will be greater where the change of velocity with depth is small, and the radius will be smaller where the change in velocity with depth is large. In other words, the path of sound will bend only slightly through layers where the change in velocity is small per unit of depth, but will bend more where the change in velocity per unit of depth is large.

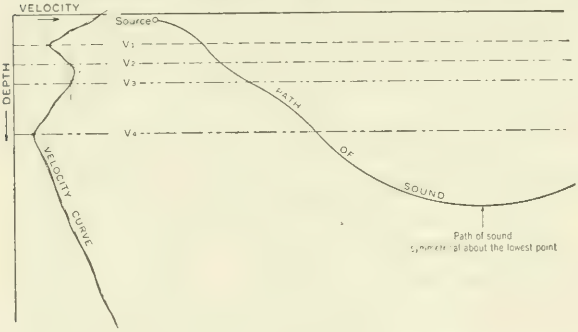


FIGURE 126.—Path of sound through water of nonuniform velocity.

The velocity-depth curve is not always as simple as that described above. In certain regions subsurface layers of warm water will cause a change of sign of the velocity gradient. In figure 126, a case is illustrated where the velocity decreases from the surface to a depth where it increases because of a subsurface layer of warm water. Below this layer, the velocity again decreases until depths are reached where the velocity starts to increase due to pressure. On the right side of figure 126, is shown the path of the refracted sound through each layer for a given angle of emergence of the sound. (Angle of emergence and initial angle are used herein interchangeably referring to the direction of the sound wave as it leaves its source.)

From a point source, the sound energy travels away in all directions at equal intensity. The sound wave can therefore enter these layers, where the velocity gradient differs, at a multitude of angles. The incident angle is the angle between the sound path and the normal to the layer boundary. The curvature of the sound path in each layer will be the same for each angle but the lengths of the arcs between the layer boundaries will be different. Where the sound enters a layer at a large incident angle, the length of the arc in the layer will be longer than where this angle is small. For each angle of propagation from the source, assuming an infinite depth of water and no loss of energy, the sound will be refracted back to the water surface, except for the ray of sound propagated vertically downward. In such a hypothetical case, that part of the energy propagated most nearly downward, without being precisely vertical, will travel the longest horizontal distance before striking the surface of the water.

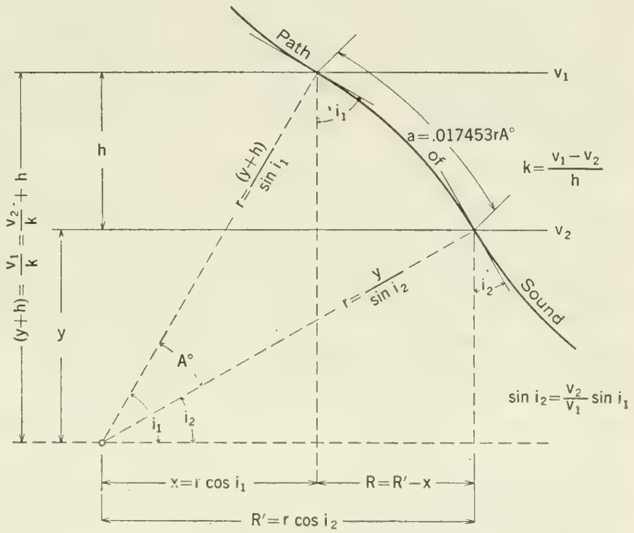


FIGURE 127.—Path of sound through a layer with uniform velocity decrease from $v_1$ to $v_2$.

The path of refracted sound through the water for any shape of velocity-depth curve, can be predicted by making certain allowable assumptions. Where the velocity as a function of depth is known, it can be plotted as in figure 126. For the purpose, it is assumed that the velocity-depth curve is the same throughout the region to be considered. This curve is then divided into segments, each of which can be represented as a straight line whose slope is the average slope of that segment of the curve. Theoretically an infinite number of straight lines of infinitesimal length would have to be used. However, it has been found that a fair degree of accuracy can be obtained by dividing the curve into a limited number of straight lines depending on the character of the curve. At least five lines should be used for a curve having an irregular shape, but for a curve of regular shape a lesser number may suffice. The ends of one of these lines projected horizontally onto the ordinate scale of the curve give the

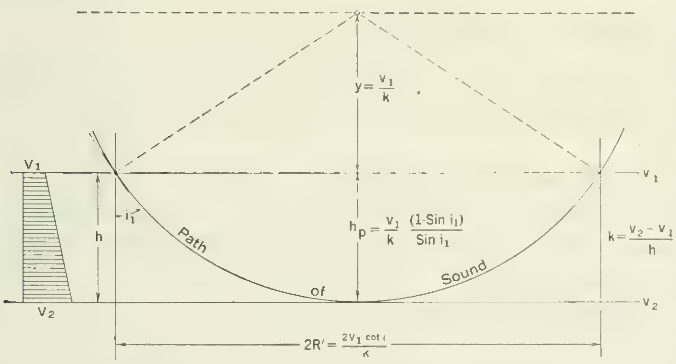


FIGURE 128.—Path of sound caused by a velocity increasing uniformly with depth sufficient to refract the sound wave back toward the surface.

upper and lower depths of the layer through which linear velocity change per unit of depth is assumed. The projection of the line on the abscissa scale of the curve gives the range of velocity throughout this depth. With these data the lengths of the arc paths and the total horizontal distance can be computed. The earth's curvature is neglected for the distances involved. A number of angles of emergence of sound are assumed and the refracted paths are computed through each layer. All the arc distances are summed and the projections of the arcs on the horizontal are likewise summed for each initial angle assumed. Each angle will give a different total horizontal distance and arc length.

The formulas for making these computations through a single layer are given with figure 127. The values required are $R$, the horizontal component of travel, and $a$, the length of arc traversed by the sound. The radius of curvature of the sound path through any layer is equal to the initial velocity $v_1$ divided by the product of the velocity gradient within the layer and the sine of the incident angle. The angle $i_1$ is the incident angle of the sound ray on entering the layer and from this the angle at which the sound leaves the layer may be found from the formula:

$$i_2=\sin^{-1}\left(\frac{v_2}{v_1}\sin i_1\right).$$

This is all that is necessary to calculate the horizontal distance $R$ and the arc distance $a$ by the method indicated in figure 127. If $v_1$ is less than $v_2$ the same method is used except that the center of radius of curvature will lie above the layer.

Where the sound path does not penetrate through the layer, the method of computing the distances is shown in figure 128. This illustrates a result commonly found in deep water, where the refraction due to increasing velocity caused by the increase in hydrostatic pressure with depth, reverses the direction of propagation back toward the surface (see **6222**). The total horizontal distance and the total distance along the curved path traversed by the sound are found, if the depth of water can be assumed to be composed of layers, by adding the distances for each layer through which the sound passes.

### *6233. Reduction of Sound Energy*

As discussed in **621** and **6224**, the reduced sound energy at the point of reception may be due to the following: spreading, absorption, reflection, refraction, diffusion, diffraction, and interference.

From a nondirective source, sound is propagated in all directions. The sound intensity would decrease in proportion with the square of the distance from the source if there were no other form of energy reduction. This reduction due solely to distance is termed spreading and has been discussed in **6224**. But it is known from observation that the sound intensity decreases much more rapidly than this.

Absorption may account for part of the additional loss. The absorption due to viscosity and thermal conductivity is relatively small at the frequencies associated with R.A.R. (see **656**). Most of the absorption that takes place is because of gases in the water. Gases in water may result from turbulent surface conditions or from the presence of marine life. Gases are mostly found in the layers of water close to the surface. Where the water is shoal, however, this layer may be a large percentage of the total

depth and may partly account for the rapid attenuation of sound in shoal water in contrast with deep water. The amount of absorption of this type is far from constant—the condition of the sea surface, the season of the year, and other factors affect the amount and depth of gas penetration.

Reflection and refraction at the boundaries of the medium account for some loss of sound energy. As stated in **6222** and **6224**, the sound energy leaving the water medium at the boundaries is quite small. A greater impedance to sound transmission, connected with reflection, is that due to the scattering of sound from the reflecting boundaries. This scattering reduces the sound energy traveling in the general direction of the point of reception. Scattering is caused by irregularities of the bottom and surface boundary. This is called diffuse reflection.

The influence of diffraction on subaqueous sound ranging is not fully known. It seems probable that some diffraction is caused by certain types of bottom and other factors, but it is believed that its effect is negligible.

Experience has disclosed that sound will be attenuated less when traveling through water of a uniform temperature. Such a condition is approached in the waters off the Pacific Coast where the transmission of sound is excellent in contrast with that in waters off the Atlantic Coast during the summer. But during the winter the surface waters off the Atlantic Coast cool sufficiently to make the temperature more nearly uniform from surface to bottom and then sound is transmitted nearly as well as in the Pacific. Transmission of sound through water of nonuniform temperature will be subject to refraction of a complex character, which will lead to greater loss of effective sound energy due to diffuse reflection, absorption, and the creation of complex interference patterns.

## 63. VELOCITY OF SOUND

To determine a distance by the transmission of sound in any medium it is necessary not only to measure the travel time accurately but also to know the effective velocity at which the sound travels. For use in echo sounding and R.A.R., electromechanical instruments are available with which the travel time of sound may be measured very accurately, but methods of determining the velocity are less reliable.

In echo sounding the sound wave passes vertically through the water from near the surface to the bottom and the determination of velocity is comparatively simple, for it is only necessary to calculate the mean velocity for the vertical column of water (see **561**).

For R.A.R., the effective *horizontal* velocity between the source and the point of reception is required, and to find this is more difficult because the sound wave is seldom propagated horizontally in a direct path, but generally follows a refracted and reflected path, as described in **6231** and **6232**. For plotting purposes, the *apparent horizontal* velocity of sound is used (see **6343**), and this can be determined experimentally by measuring the travel time of the sound wave between two points a known distance apart. In R.A.R. surveys, frequent measurements are made over suitable known distances throughout the project area to determine this apparent velocity.

The *apparent* velocity is seldom used for echo sounding, however, principally because of the difficulty of measuring great depths directly with sufficient accuracy to determine it. Instead, the velocity is calculated from, or taken from, tables based on the physical characteristics of the water, which can be measured in situ. If the

temperature and salinity of the water at any depth are known, the velocity at that depth may be found from tables. Velocities so determined are extensively used in correcting echo soundings and are occasionally used in R.A.R.

The velocity of sound in any medium may be found from Newton's fundamental equation which is:

$$\text{Velocity}=\sqrt{\frac{\text{Elasticity of the medium}}{\text{Density of the medium}}}$$

In the case of an extended medium, the bulk modulus of elasticity is used. This modulus can be determined in a physical laboratory by measuring the change in volume produced by known forces. The condensations and rarefactions in a sound wave take place so rapidly that there is little time for the heat developed in condensation, and the cooling in rarefaction, to be transferred to the surrounding medium. The change is not isothermal—it is adiabatic and involves the ratio of specific heat at constant pressure to the specific heat at constant volume. Hence the velocity equation must be modified to allow for this fact.

The velocity of sound in sea water may be calculated from the temperature and salinity of the water and the hydrostatic pressure. An increase in temperature increases the elasticity but reduces the density; both of these changes increase the velocity, but the adiabatic correction is reduced. Salinity also affects both terms of the equation, an increase in salinity causing an increase in both the density and the elasticity, the net effect being an increase in the velocity. Hydrostatic pressure also increases both the elasticity and the density, and results in an increase in velocity. In addition to increasing with depth, hydrostatic pressure varies slightly with latitude because of the change in gravity. However, corrections for latitude may be safely ignored in R.A.R., since the maximum variation from the corrections given in table 34 is but 0.5 meter per second for a depth of 5,000 fathoms.

The velocity of sound increases with changes in the physical characteristics of the water by the following approximate percentages:

(*a*) Each 1°C. increase in temperature causes an average increase in velocity of 0.2 percent.
(*b*) Each 1.0 ‰ increase in salinity causes an average increase in velocity of 0.1 percent.
(*c*) The increase in pressure for each 100 fathoms of depth increases the velocity 0.22 percent.

Remembering that the velocity of sound in water is approximately 1,500 meters per second at temperature 14° C., salinity 35.0 ‰, and surface atmospheric pressure, the above percentages may be used to compute approximate velocities for other values of temperature, salinity, and depth.

Temperature is the most important physical characteristic of sea water affecting the velocity of sound (see **632**). To compute the velocity accurately the vertical and horizontal distribution of temperature in the water medium must be known, so the temperatures must be measured in situ. The density must also be measured to find the salinity, although it has relatively less effect on the velocity. If the depth of water is known, the change in velocity due to pressure can be readily computed.

An important fact to bear in mind is that the velocity of sound is greatly affected by the presence of suspended particles, not in solution. Sea water always contains such suspended matter, although in the open ocean it is encountered in such minute quantities it may be ignored. At some places along the coast, particularly near the mouths of large rivers, it is present in appreciable amounts, but its effect on the velocity of sound is practically indeterminable, except by experimental tests.

## 631. Practical Use of Velocity of Sound

The computation of velocity corrections for echo sounding and of distances in R.A.R. surveys are impossible unless the velocity of sound at the time of such surveys is known with reasonable accuracy. In most water areas the velocity is variable from surface to bottom and, principally because of the seasonal variation in water temperature and salinity, the velocity varies seasonally. The temperature and salinity of the water must be measured at various depths at well-distributed points in the project area and at frequent intervals, so that average values of the velocity of sound may be determined with sufficient accuracy.

### *6311. Velocity Corrections to Echo Soundings*

Because of the theoretically linear relationship which exists between the travel time required for an acoustic wave to travel between two points and the distance between them, echo-sounding instruments may be calibrated in units of depth. These instruments are described in chapter 5. In most instruments, the motion of the depth-registering device is regulated to give correct measurement for an assumed velocity of sound in water, known as the *calibration velocity.* If the actual velocity at any time differs from the calibration velocity, the registered depths must be corrected to what they would have been on an instrument calibrated for this actual velocity. This correction is known as the *velocity correction,* its magnitude varying with depth as well as with the divergence of the actual velocity from the calibration velocity. A velocity correction is based on the mean of all the velocities from the surface to the bottom for that depth. In order to determine these mean velocities, the instantaneous velocity in each of the depth layers to the greatest depths and in all parts of the project area must be known. (See also **561**.)

### *6312. Use in Radio Acoustic Ranging*

A knowledge of the velocity of sound is required in R.A.R. surveys in order to reduce the time intervals to linear distances. Sound is rarely propagated in a straight horizontal line through sea water—under the physical conditions usually prevailing it is refracted and reflected through a longer path so that the actual elapsed time is longer than it would be if the path were a straight line. It is the apparent horizontal velocity that is wanted in R.A.R., but the problem of determining it under all conditions from data easily observed is indeed complicated, if not impossible. Some method of reducing, to a horizontal basis, the measured times of sound travel along the refracted and reflected path is needed.

### *6313. Accuracy of Velocity Determination*

For use in correcting echo soundings the velocity of sound must be known with sufficient accuracy to ensure that no sounding will be in error from this cause alone by as much as one-half percent of the depth. Therefore the mean velocity of sound must be known for each sounding with an error not greater than 7.5 meters per second Of the three characteristics of sea water affecting the velocity of sound, temperature is the most variable, and to satisfy the above requirements the mean temperature of the vertical column of water at each sounding should be known within approximately 2° C. The frequency with which serial temperature observations must be made to attain this accuracy is discussed in **6322**.

For use in R.A.R. surveys the apparent horizontal velocity of sound (see **6343**) should be known with sufficient accuracy so that no error in a plotted distance is introduced from this source in excess of 1.0 mm, regardless of scale. The accuracy with which the velocity must be known depends, therefore, on the scale of the survey and the maximum length of the R.A.R. distances: for example, to plot a distance equivalent to 20 seconds of travel time on a 1:80,000 scale survey sheet with this accuracy, the velocity must be known within 4 meters per second. Obviously it is impossible to specify accuracy requirements for all of the various cases for R.A.R., but generally the hydrographer should endeavor to determine the velocity of sound within 3 to 5 meters per second. (See **6322** and **6352**.)

## 632. Temperature of Sea Water

Of the physical characteristics of sea water, temperature affects the velocity of sound to the greatest degree, particularly in shoal water. A hydrographer using echo sounding or R.A.R. must know with considerable accuracy the vertical distribution of temperature from the surface to the bottom, and the seasonal change in temperature in a given area. Temperature distribution in sea water is best studied by means of graphs. A graph of observed temperatures at a given station plotted with reference to depth is known as a *temperature curve* (see **6321**). The character of the temperature curve varies with latitude, and depth of water and ocean currents have a pronounced effect on it.

Solar radiation is the principal agent affecting, either directly or indirectly, the temperature of sea water. Water has a high thermal capacity, consequently the water near the surface is at a maximum temperature following the hot season of the year and at a minimum temperature following the cold season. In the waters usually surveyed by the Coast and Geodetic Survey the summer maximum is generally reached in late September or early October, the winter minimum occurring in late February or early March.

*a. Thermocline.*—The temperature of the waters near the terrestrial poles is nearly uniform from surface to bottom, and there is very little seasonal variation. In lower latitudes, during the warmer months, the surface water is heated and there is generally a layer of warm water above the colder water. A decrease of temperature is, therefore, to be expected in sea water as the depth increases. The surface heat is transferred downward by conduction, convection currents, and the stirring of the surface water by wind and waves. The thickness of this upper layer of warm water varies with locality, but it is generally less than 40 fathoms (see figs. 129 and 130). It has been called the *epithalassa*, the colder water below being known as the *hypothalassa*. Between the warm surface water and the colder water below, there is a layer in which the temperature changes rapidly with depth. Such a temperature gradient is known as a *thermocline*. Thermoclines are very important in subaqueous sound ranging, for when they are marked, as they generally are during the summer months, a sound wave is refracted rapidly downward. During the colder months the temperature gradient is much less marked. Hence, thermoclines have a great effect on the range at which subaqueous sound can be received, and on the apparent horizontal velocity.

*b. In open-ocean areas.*—In the open ocean, to moderately high latitudes, there is generally a layer of water of variable depth, below approximately 75 fathoms, in which the temperature decreases rather rapidly with depth. At the bottom of this layer

the temperature approaches a minimum and becomes relatively constant, usually at a depth not greater than 400 fathoms. The temperatures in this layer are relatively stable and are generally only slightly affected by the seasonal variation in atmospheric temperature. This layer might be called the *stationary thermocline.* (See fig. 130.)

Above the stationary thermocline the temperature is unstable throughout a layer whose thickness varies with latitude and other characteristics of the area. Its temperature varies rapidly with respect to depth, and in summer the seasonal thermal progression raises its temperature far above that of the stationary thermocline. It might be called a *summer thermocline.* The summer thermocline may extend from the surface downward to join the stationary thermocline, but it is unstable, because wind, surface waves, and changes in density cause mixing in the surface layers. This mixing has been observed to extend to a depth of 35 fathoms during a storm. Consequently, above the summer thermocline there is generally a layer of variable thickness in which the physical characteristics, excepting hydrostatic pressure, are nearly uniform.

*c. Coastal waters.*—The temperature conditions in waters on the Continental Shelf, or near land, are generally different from those found in the open ocean, for the temperatures throughout the entire depth of water generally experience a seasonal cycle and the stationary thermocline is seldom evident. The summer thermocline is generally more pronounced in shoal water than in the open ocean. Occasionally there is a layer of colder surface water that has been moved inshore from the open ocean by winds causing what is known as a *temperature gradient reversal.* Where such temperature reversals are experienced, R.A.R. is usually difficult in operation.

In some localities and over offshore shoal areas, where there are strong currents and winds, the temperature curve is vertical (if plotted as shown in fig. 129) during

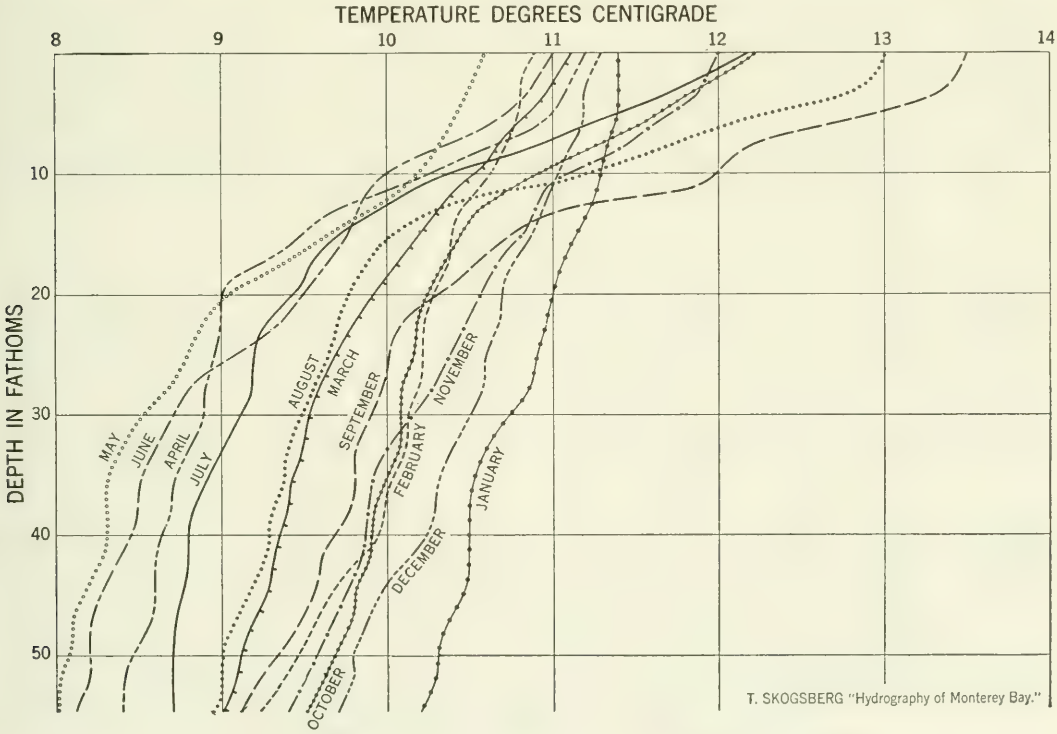


FIGURE 129.—Annual cycle of temperature distribution in sea water near the surface.

most of the year, and only during warm months with clear skies will the heat absorption be sufficient to form a summer thermocline.

In high latitudes as winter approaches, the summer thermocline begins to disappear. The surface water begins to cool, and the consequent change in density causes

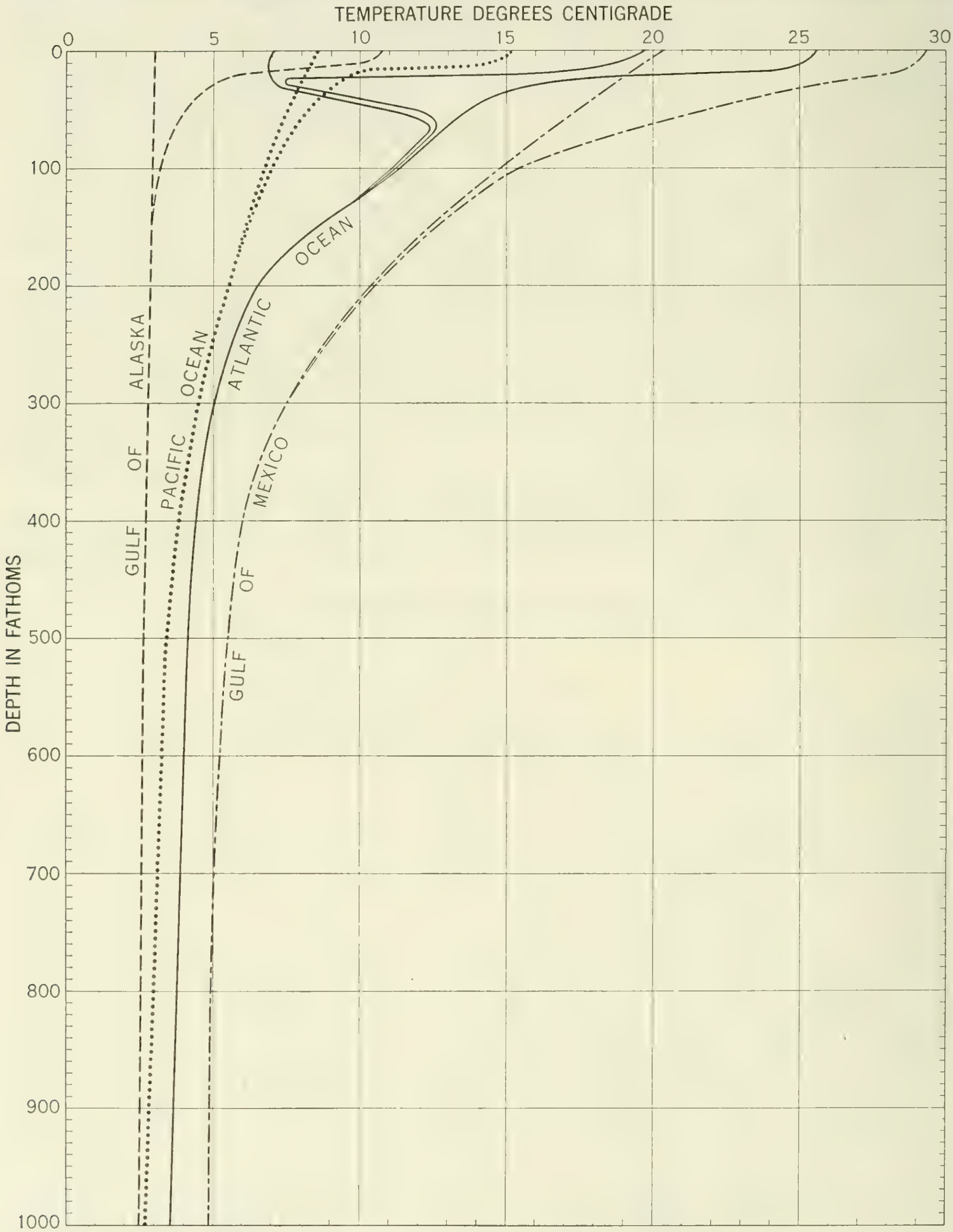


Figure 130.—Range of temperature curves in offshore ocean waters.

convection water currents, thus mixing it with the layer below. In the colder months there will often be a layer of cold water overlying a layer of warmer water, below which the temperature will gradually decrease with depth, also forming a temperature gradient reversal.

*d. Seasonal temperature distribution.*—An annual cycle of the average monthly vertical distribution of temperature in Monterey Bay, California, to a depth of 55 fathoms is shown in figure 129. The observations were made in 1933 at a station inshore, where the temperatures are much affected by wind currents. The cycle is not necessarily representative of offshore temperature curves. The lag in the temperature of the water with reference to the seasons is attributed partly to the fact that when the temperature of the water rises, evaporation tends to check the rapidity of the rise; and when it falls, condensation of water vapor in the layer of air overlying the surface checks the rapidity of the fall.

*e. Diurnal variation.*—In addition to the seasonal change there is a diurnal variation in the temperature of the surface water. During the day the temperature of a very thin surface layer of water is increased a few degrees, depending on the latitude and the time of year. This may be called a *diurnal thermocline.* Unless the surface of the water is disturbed so that the heat is transferred downward, most of this heat is lost during the night. This diurnal variation in temperature has little appreciable effect on the velocity of sound and is generally disregarded.

*f. Temperature ranges in offshore areas.*—The approximate extreme ranges of temperature in the offshore waters adjacent to continental United States and Alaska are shown in figure 130. The Alaska curves are from serial temperatures (see **6321**) taken in the northern part of the Gulf of Alaska. The Pacific Ocean curves are for locations offshore in the approximate latitude of San Francisco and they probably represent average conditions for that locality. The curves for the Gulf of Mexico are from observations in the western part. They are very similar to the curves for the waters adjacent to the Hawaiian Islands. The curves for the Atlantic Ocean represent conditions off the Continental Shelf in the approximate latitude of Washington, D. C. The Atlantic Ocean curves are interesting; two of them represent the approximate extreme ranges and the third an extreme temperature gradient reversal.

### *6321. Temperature Observations*

The observations required to determine the vertical distribution of temperature and salinity with depth at any one place in the ocean are known as a *serial temperature.* The temperatures must be measured in situ, and water samples, from which salinities may be determined, must be trapped at various depths and brought to the surface uncontaminated by water from other depths. The temperature is measured and the water samples are obtained with special instruments designed for the purpose which are described in section **47**.

The maneuvers of the ship and the precautions to be observed while measuring a serial temperature are generally the same as those required while taking a wire sounding, as described in **3422**. The oceanographic instruments used by the Coast and Geodetic Survey are designed to be clamped on a line larger in diameter than stranded sounding wire or piano wire, so a few fathoms of leadline must be placed between the end of the sounding wire and the lead, to which they may be clamped. The water specimen cup is clamped about 1 fathom above the top of the lead and the reversing

thermometer frame is clamped high enough above it so that the thermometer holder, when reversed, will not strike against the watercup.

A sounding lead weighing about 35 pounds is generally used when serial temperatures are observed. The water specimen cup and the thermometer frame add a considerable weight, and the risk of overloading the wire must be avoided at all costs. Depending on the strength of the sounding wire, the power of the sounding machine, and economy of time in making the observations, a detachable weight with a Belknap-Sigsbee specimen cylinder (see **4665** and **4744**) should be used in place of a lead in depths greater than 700 fathoms.

Most serial temperatures observed by the Coast and Geodetic Survey are in depths less than 150 fathoms, so at least this much stranded sounding wire should be next to the lead on the sounding machine used for this purpose. The wire should be renewed at the first indication of appreciable wear to avoid unnecessary loss of instruments, equipment, and time.

No thermometer shall be used for serial temperatures unless it has been standardized (see **4712**).

The temperature of the water near the surface may be measured with a reversing thermometer in a frame attached to a hand leadline which is used to pull the thermometer through the water until the frame reverses.

The bottom temperature observation of a serial temperature should be made after the registering sheave has been set at zero with the bottom of the lead at the surface of the water. For intermediate depths the sheave should be set at zero with the reversing thermometer at the surface of the water. For each observation, the reading of the sheave should be checked as the instruments emerge from the water.

The sounding-machine operator should be trained to handle the machine properly. On the descent the machine must not be stopped suddenly and on the ascent it must not be started with a jerk, because either may part the wire. The operator should allow very little slack in the wire when the lead touches bottom. For temperature observations at intermediate depths between the surface and the bottom the operator is sometimes unable to stop the machine at exactly the desired depth, with the result that the depth is greater than desired. Such errors must not be rectified by reeling in a few fathoms, because of the likelihood of reversing the thermometer. The sounding-machine operator must be instructed to read the actual depth of each observation from the sheave, irrespective of the desired depth.

The officer-in-charge of the observations should see that the thermometer is kept at each depth long enough to register the correct temperature. The time required depends on the design of the thermometer but not more than 2 minutes is required for any type of reversing thermometer now in use.

The various depths at which observations for a serial temperature should be made cannot be specified in advance for waters for which the character of the temperature curve is unknown. The aim should be to obtain a sufficient number of observations to define the curve accurately. In most localities more closely spaced observations are required in the upper layers where the greatest temperature variation occurs, than in deeper water where temperature conditions are more stable.

For all serial temperatures, an observation should be made at 2 fathoms below the surface, which is the approximate depth of the oscillator and hydrophone on most survey ships. Where the character of the temperature curve is unknown, observations should be taken at approximately 10, 20, 30, 40, 50, 75, 100, 150, 200, 300, 500 fathoms

below the surface, and at the bottom in depths of 1,000 fathoms or less. For depths greater than 1,000 fathoms, the same observations should be made down to 500 fathoms, supplemented by an observation at each 1000-fathom level below the surface and an observation at the bottom. (See **6342.**)

Where there are temperature gradient reversals, additional observations may be required in the upper 100 fathoms to define the temperature curve accurately, but where the temperature changes are regular with reference to depth, fewer observations will often suffice. After the general character of the temperature curve in an area is known, depths for observations may be selected so that fewer observations are required. In many areas where the deep-water temperatures are stable, observations are necessary only in the layers near the surface.

All the observations of a serial temperature should be taken at the same place, but this is frequently difficult in deep water, for the ship may drift a considerable distance in the 2 or 3 hours required for the observations. To approximate the same location, the time required for the observations should be reduced to a minimum so the drift of the ship will not be appreciable, or the vessel must be maintained at the same place by maneuvering. In a serial temperature observed with only one set of instruments where the depth is known by echo sounding, the temperatures in the variable upper layers should be observed first before the ship drifts away from the position. Where the depth is unknown, it is advisable to take the bottom observation first so those above it can be spaced to the best practicable advantage; after the bottom observation, the remaining observations should be from the surface downward.

Within sight of an anchored buoy the ship may be maintained at approximately the same position by bearing and distance observations on the buoy. In the open ocean, beyond the visibility of any objects, approximately the same position may be maintained by knowing the general direction and velocity of the current and maneuvering the ship to maintain the same depth on the echo-sounding instrument. Maneuverin the ship during a serial temperature is generally undesirable because of the excessive time required to place the ship in position for each observation. The best method is to effect a reduction of the total time required for the serial.

The use of the bathythermograph (see **473**) to record the variable temperatures in the upper layers of water will reduce the required time materially. For a hydrographic party not equipped with a bathythermograph, other expedients may be used to reduce the time. Two reversing thermometers may be used on two sounding machines, one for the observations from the surface downward and the other for those from the bottom upward. This method reduces to about one-half the time required for a serial temperature, but more personnel are required and there is some risk of fouling the two sounding wires. Another method is to use a number of reversing thermometers attached at selected intervals on one sounding wire—a heavier sounding wire than ordinary stranded or piano wire must be used to ensure against possible loss of all the instruments through the parting of the wire.

Surface water temperatures are generally not measured for use in echo sounding, but in the determination of velocity for R.A.R. they may be required. The surface temperature should be measured with a reversing thermometer as described above but, if this is not practicable, a bucket of water, uncontaminated by any discharge from the ship, may be drawn from the surface and its temperature measured. The latter method is not entirely satisfactory, because cooling may reduce the temperature by a half degree under ordinary conditions, and in winter, when the water is much warmer than

the air, it may cause an error of as much as 5° C. The canvas bucket, used for the surface haul, should be constructed as if it were two buckets, one inside the other, with an air space between for insulation; the outside should be painted so that it sheds water. The haul must be made quickly and the temperature taken with a quick-acting thermometer as soon as the sample is on deck.

### *6322. Frequency of Observations*

For use in echo sounding and R.A.R, it must be assumed that the velocity of sound is relatively constant throughout certain areas and during certain periods of time. For economic reasons the values used cannot be changed too frequently. The length of time during which the velocity may be assumed to be constant will vary from an entire season to a 2-week period on the working ground, and the area will likewise vary from that surveyed in an entire season to that surveyed in a 2-week period. This assumes that the temperature and salinity of the water remain relatively constant. A sufficient number of serial temperatures must be observed so that the velocity may be known with the accuracy specified in **6313**. The number required depends on the physical characteristics of the water and the physiography of the area. The proximity of an ocean current or the discharge from a large river would necessitate more frequent observations, in which particular attention would have to be given to the salinity determinations.

At least one complete serial temperature should be observed in the deepest part of the area surveyed each month, for use in computing corrections to echo soundings.

Where little is known about the regional variation in temperature, the first monthly deep-water serial temperature of a season should be accompanied by a second one in deep water at a different locality, down to depths where the temperatures of the two are in approximate agreement. In the limited areas ordinarily surveyed during 1 month it will usually be found that this will occur comparatively near the surface (generally within 75 fathoms of it) in the layer where the influence of the seasonal change is greatest. Where this is the case, other serial temperatures taken during the month may be restricted to the upper layers, possibly to the depth limit of the bathythermograph. The hydrographer should endeavor to determine the regional and seasonal variation in an area with a minimum number of serial temperatures at positions distributed throughout the area.

Physical conditions of sea water are rarely so stable that one serial temperature will suffice for the duration and area of a survey. Practically, however, even assuming such a condition, additional observations must be made at intervals to prove the stability. Where there is little regional variation and only a slight seasonal change, a minimum of four or five well-distributed serial temperatures each month should suffice. Where the physical characteristics are extremely variable, both regionally and seasonally, as during the summer months along the Atlantic Continental Slope in the vicinity of Nantucket Island, Massachusetts, a minimum of about 15 serial temperatures should be observed each month. In such conditions it is better to take too many observations rather than too few to ensure that the requirements specified in **6313** will be met.

For most localities there is insufficient knowledge of the physical conditions to enable the hydrographer to predict the temperature gradient or to extrapolate a temperature curve far beyond an observed value, so he must depend on his own observations. But prior surveys in an area or published studies by other organizations may

be of assistance in determining how frequently serial temperatures should be obtained. Such data have been published for the Atlantic Ocean from Cape Cod to Chesapeake Bay [1] and for the Gulf of Maine.[2] An extensive study of the temperature of the water in Monterey Bay, California [3] has also been published.

For economic reasons serial temperatures are frequently observed at night, and when R.A.R. surveys have to be discontinued because of heavy static. A hydrographer should take advantage of every opportunity to obtain serial temperatures and, if practicable, without interfering with other survey operations. Using the bathythermograph a serial temperature may be observed while weighing a buoy or while taking a vertical wire sounding. The Bourdon-type bathythermograph (see **4732**) can be used from the ship underway, for the temperatures of the upper layers, without delaying other hydrographic operations. Serial temperatures outside the limits of the survey area, observed at night after anchoring or in the morning before getting underway, are generally of little value, for such temperatures will seldom be representative of the area being surveyed.

### 633. Salinity of Sea Water

The composition of sea water is as complicated as the composition of the land, for it is obvious that every soluble substance on land will eventually be carried to the sea. In addition to the salts soluble in water, rain water in passing through the atmosphere absorbs acids. This enables it to dissolve the minerals of the earth into soluble compounds and carry them to the sea where they either remain in solution or form insoluble compounds which sink to the sea bottom. Sea water is, therefore, a dilute solution of a number of salt compounds which are strong electrolytes.

For the sake of simplicity the total amount of dissolved solids in sea water has been arbitrarily designated as the salinity. Salinity is then defined as the total number of grams of solid material dissolved in 1 kilogram of water; it is expressed in parts per thousand, which is written ‰. The amount of solids may also be expressed in terms of chlorinity, which is defined as the total amount of chlorine present in 1 kilogram of sea water. A constant relationship has been found to exist between salinity and chlorinity, expressed by the equation

$$\text{Salinity} = 0.03 + 1.805 \times \text{chlorinity}.$$

Salinity is, therefore, just another form for expressing chlorinity, but it is only indirectly related to the total true salt content, with which it is often confused. Oceanographers prefer the use of the term chlorinity in describing the nature of the water, but the Coast and Geodetic Survey uses the term salinity exclusively. When the titration method is used the equipment is calibrated to give the results in terms of salinity. This is desirable because the velocity of sound tables have been prepared in terms of salinity.

Average sea water contains about 35 ‰ of solids in solution, of which sodium chloride (27.2 ‰) and magnesium chloride (3.8 ‰) are two of the principal constituents; but there are many other salt compounds in the form of bromides, fluorides, iodides, and carbonates—some in such small proportions as to be negligible in quantitative chemical analysis. Some compounds are absorbed by marine animals, plants, and organisms

[1] Woods Hole Oceanographic Institution, Volume II, No. 4, Studies of the Waters of the Continental Shelf, Cape Cod to Chesapeake Bay, Part I, The Cycle of Temperature.

[2] Bureau of Fisheries Document No. 969, Physical Oceanography of the Gulf of Maine.

[3] Transactions of the American Philosophical Society, New Series—Volume XXIX, Hydrography of Monterey Bay, California, Thermal Conditions, 1929–1933.

and are temporarily removed from solution but these are eventually redissolved. Sea water also contains gases and traces of a vast number of organic compounds. Some of the gases, notably oxygen, remain in true solution, but others soon combine with other substances in the sea water. Of all the dissolved substances that reach the sea, only the volatile ones are removed by evaporation to the atmosphere.

A study of a number of analyses of the composition of sea water from all regions of the world shows that sea water, regardless of locality, is of uniform composition and varies only as to the percentage of total salts held in solution. The salinity is usually high in regions where atmospheric temperature and evaporation are high and rainfall is small, and vice versa. Rain water and water from rivers tend to float on the surface of the sea and because of this the salinity near the surface is less than at greater depths. For the same reason the salinity near shore is generally less than in the open ocean. In some regions the salinity will vary considerably from surface to bottom and from place to place. At one place in the Gulf of Mexico the salinity has been observed to differ by 6 ‰ from the surface to bottom in only 8 fathoms of water. In the same locality the surface salinity has been observed to differ by 8 ‰ at two places only 10 miles apart.

### *6331. Determination of Salinity*

The salinity of sea water varies with the density of the water, and the simplest method of determining the salinity, for use in hydrographic surveys, is to measure the relative density, or specific gravity, with a hydrometer. Hydrometers and specific gravity measurements are described in **475**, and the method of recording the observed data on Form 717, Record of Temperatures, Salinities, and Theoretical Velocities, is described in **6341**. The salinities, which are determined from the specific gravity measurements by the use of tables or a graph, are also recorded on Form 717.

The density of sea water depends not only on the amount of soluble matter contained in a unit volume, but also on the temperature of the water. Sea water expands and becomes lighter when heated and contracts and becomes heavier when cooled. Therefore, the specific gravity by hydrometer must be corrected for any variation of the water sample temperature from the standard of 15°C., for which the salinity tables are computed; consequently the temperature of the water at the time of the specific gravity measurement is needed to determine the salinity (see **475**). The corrections for temperature and instructions for applying them will be found on pages 86 and 87 of Special Publication No. 196 (1941 edition), Manual of Tide Observations. Observed density, measured specific gravity, and apparent density or specific gravity are all one and the same, and refer to the hydrometer reading uncorrected for temperature. With the corrected density, the corresponding salinity may be found from the table on page 88 in Special Publication No. 196.

The salinity may also be found from a graph constructed from the values in the tables for the required ranges of observed data. Figure 131 includes the range of salinities from 28 to 40 ‰. It may be seen from the figure that a change of 7 or 8 in the fourth decimal place of specific gravity is required to produce a change of 1‰ in the salinity. The hydrometer may generally be read accurately to 1 in the fourth decimal place, so that the salinity may be determined with a theoretical accuracy of almost 0.1 ‰.

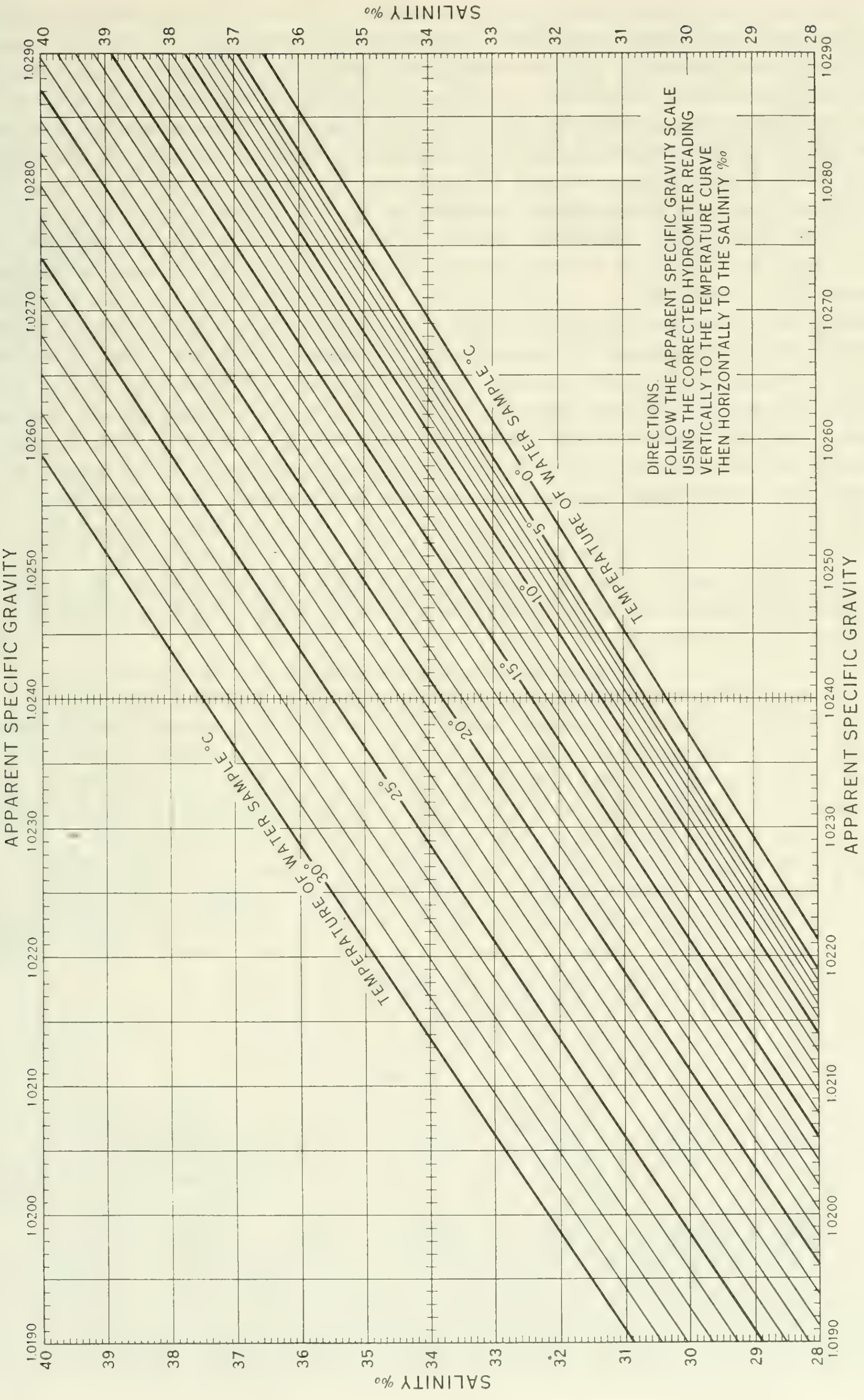


FIGURE 131.—Graph to convert apparent specific gravity to salinity.

Salinity may also be determined by chemical titration. This method is based on the fact that the proportion of chlorine in the total dissolved solids is nearly constant in all sea water (see **633**). A silver nitrate solution of known strength is used to precipitate the chlorine as silver chloride and a small quantity of potassium chromate solution, free from chlorides, is used as an indicator. The instruments and method of chemical titration, as well as other methods of determining salinity, are described in Special Publication No. 147, Measurement of Salinity of Sea Water.

Water samples are ordinarily not retained unless they are desired for scientific purposes: Field parties sometimes survey in areas where few scientific analyses of the water have been made and water samples from such areas are frequently desired by oceanographic institutions. Special instructions will be issued by the Washington Office in such cases and the oceanographic institution will generally furnish specimen bottles and issue directions for preserving the samples and instructions for shipment, which is usually made at the expense of the institution. The specific gravity of such water samples is immediately measured by hydrometer in the usual manner, so that the salinity may be determined for immediate use, and the sample is then bottled and marked for identification. The salinities of water samples sent to oceanographic institutions are generally furnished later to the field party. They should be recorded in the proper spaces on Form 717 and used in the velocity computations, if received in time.

A graph of the salinities with reference to depth should be plotted for every serial temperature observation, in the space provided on Form B-1528-5 on which the serial temperatures are plotted.

### *6332. Frequency of Determinations*

The range of salinity is usually small, and compared to temperature it has comparatively little effect on the velocity of sound. It usually increases uniformly with depth. In general a water sample for use in determining the salinity should be obtained at the surface and bottom as a part of each serial temperature; and a sample at one intermediate depth should be obtained occasionally. The salinities for other depths may usually be interpolated with sufficient accuracy from the salinity curve. Determinations of salinity should be well distributed as to area and throughout the season and should yield sufficient information to ensure the accuracy specified in **6313**. Where the temperature varies erratically, the salinity will usually vary in a similar manner and additional salinity determinations will be required.

## 634. RECORDS AND COMPUTATIONS

### *6341. Records of Observed Data*

The observed temperatures and the observations to determine the salinity in a serial temperature, and all scattered observations of temperatures and salinities, must be recorded on Form 717, Record of Temperatures, Salinities, and Theoretical Velocities. This form contains a number of columns in which the data should be entered; one horizontal line should be used for each observation at each different depth.

The form is designed for use in recording both serial temperature observations and scattered bottom or surface observations. A separate copy of the form should be used for each serial temperature, the date of the observation being entered only on the date line at the top of the form. When the form is used to record scattered bottom or

surface observations, a number of these may be recorded on one copy, the date of each observation being entered in the left-hand column. The time of a single observation should be recorded in the proper column, but only the times of beginning and completing a serial temperature need be recorded. The depth of an observation should be indicated to the nearest half fathom for the first 100 fathoms below the surface and to the nearest fathom for greater depths. Care must be taken to record the actual depth of observation. The bottom observation should be indicated by a *B* after the recorded depth. Where the position of an observation is known accurately, the latitude and longitude should be given to the nearest tenth of a minute, but for a serial temperature, where the ship has drifted considerably, the probable mean position to the nearest half minute is all that is warranted.

The observed temperatures should be read and recorded to the nearest tenth of a degree centigrade and the corrected values entered in the column provided for that purpose (see **4713**).

Four columns are provided for the data to determine the salinity by hydrometer. Under the two columns headed "Specific gravity," spaces are provided for recording the observed density, or apparent specific gravity, and the corrected observation. To the right of these is another two-column space headed "At temp." in which the observed and corrected temperature of the water sample should be entered. (See **6331**.) The maker's numbers of the reversing thermometer and the hydrometer—not the National Bureau of Standards numbers—should be recorded in the spaces provided.

In the "Remarks" column the character of the bottom should be recorded on the same line with the observations at the bottom depth. In this column the state of the weather and the condition of the sea should also be entered.

The salinities determined from the specific gravity measurements, and the velocities computed from the temperature, salinity, and depth determinations, are also recorded on Form 717. The determination of salinities from the observations is described in **6331** and the computation of velocities is described in **6343**. Salinities determined by titration, or by any other method, are also recorded on this form.

Rubber Stamp No. 40 should be used in the lower right-hand corner of the form and the initials of the persons who observed and recorded the data, computed the salinities and velocities, and checked the computations, should be entered in the spaces provided.

### *6342. Temperature and Salinity Graphs*

Simultaneously with the serial temperature observations, the corrected temperatures and the salinities should be plotted as graphs on Form B-1528-5, designed for this purpose. This should always be done to ensure that the number of observations is sufficient and that they are correct. The temperature and salinity graphs aid in detecting any erroneous observations and in determining at what depths additional observations are required. If there is any uncertainty in drawing any part of the temperature curve, additional observations should be taken.

In most localities the temperatures in the upper layers of water generally cover a wider range and are more variable. Therefore, in plotting the temperatures on Form B-1528-5, the curve should be plotted in two sections; a shoal section from the surface to 100 or 120 fathoms, and a deep section from 100 to 1,200 fathoms. The whole of the depth range of the ordinate scale should be used for both curves, the shoal section being on a scale 10 times as large as the deep section. The temperature at 100 or 120 fathoms

should be shown on both curves. Only one serial temperature shall be plotted on a sheet. Where a serial temperature extends into depths greater than 1,200 fathoms, the observations at depths below 1,200 fathoms should only be recorded on Form 717, but a notation should be added at the bottom of the graph stating the maximum depth of observations. For the sake of uniformity serial temperatures shall be plotted only on Form B-1528-5, and only at the specified scales.

The temperature and salinity curves may be inked any time after a serial temperature has been completed. The two sections of the temperature curve may be inked as heavy black lines, unless they cross and there is probability of confusion, in which case the deep section should be inked in red. Each observed value should be indicated by a small circle. The depth of some one observation on each curve, or on each section if there are two, shall be indicated in numerals.

The graphs of serial temperatures, with the records of observations, should be arranged in chronological order and bound together and forwarded to the Washington Office. They should not be bound with any other report or records. (See **8331**.)

### *6343. Computation of Velocities*

As stated in **63**, the velocity of sound in sea water depends on the temperature, salinity, and pressure. Therefore, if the temperature and salinity are known at any depth, the velocity of sound at that depth may be computed from tables 32, 33, and 34 in **9611**. These tables are based on Tables of the Velocity of Sound in Pure Water and Sea Water, H. D. 282, published by the Hydrographic Department of the British Admiralty. Table 32 contains the velocity in meters per second for various temperatures under atmospheric pressure and at a salinity of 35.0 ‰. The correction to be applied to the velocity in table 32 for the difference between the actual salinity and 35.0 ‰ is given in table 33, the correction being subtractive where the actual salinity is less than 35.0 ‰ and additive where it is greater. Table 34 gives the correction for pressure, to 4,000 fathoms, to be applied to the velocity in table 32; it is always additive. The pressure correction varies not only with hydrostatic pressure but also with gravity and therefore with latitude. Table 34 is computed for latitude 45°, a mean value sufficiently accurate for surveying purposes (see **63**). The pressure correction is relatively uniform and for depths less than 1,000 fathoms it may be found by dividing the depth in fathoms by 30, which will give the correction in meters per second.

Velocities are derived on Form 717 from entries made from the above tables. Using the "corrected temperature at depth," the velocity found from table 32 is entered in the column headed "Velocity at temp." The corrections to this value for salinity and pressure at depth of observation are found from tables 33 and 34, respectively, and, with their algebraic signs, are entered in the double column headed "Corrections." The algebraic sum of these three column entries is entered in the column headed "Velocity (theoretical)." This value is the computed velocity of sound in sea water at the depth of the observations. Velocities are usually computed and recorded to tenths of a meter per second.

Echo-sounding corrections and occasionally velocities for use in R.A.R. are based on theoretical velocities, meaned from the surface to the various depths of water. The temperatures and salinities, for a period of time in which they can be assumed to have remained approximately the same throughout an area, are used (see **5612**).

The velocity for each depth at which observations are made in a serial temperature is usually computed and entered on Form 717. Instead of graphs of temperature and

salinity (**6342**), the velocities may be plotted with reference to depth on cross-section paper and a graph may be drawn to represent the velocities at all points through a vertical column of the water. In the same manner that temperatures and salinities are combined, the velocity curves may be combined and an average velocity curve drawn, from which a mean velocity from surface to each depth may be determined. Velocity gradients affect the propagation of sound in sea water to a great extent, and they are of utmost importance in R. A. R. Even a graph of the temperatures plotted with reference to depth will reveal the approximate character of the velocity gradient in the upper layers, where temperature changes are relatively large.

R.A.R. smooth sheets are frequently plotted by using velocities determined experimentally; that is, by measuring the travel time of a subaqueous sound between two points whose horizontal distance apart is known. The distance divided by the elapsed time gives the velocity of forward propagation. Such a velocity is known as an *apparent horizontal velocity*, because it may differ from the actual velocity of the sound wave in the medium, due to the propagation path of the wave (see **623**). It is, nevertheless, the value that is needed for plotting distances in R.A.R. Apparent horizontal velocities are satisfactory for use in an area where the velocity increase with depth is nearly uniform from surface to bottom; but where the velocity decreases appreciably with depth, apparent horizontal velocity can be used with accuracy only for distances and depths approximately the same as those where the test was made and for limited periods of time in the same locality.

Apparent horizontal velocity is frequently determined from the elapsed time required for a subaqueous sound to travel between two buoys, the distance between them having been measured by taut wire. In an area adjacent to prominent shore signals or high mountains which have been accurately located, it is generally determined from elapsed times from R.A.R. stations to positions fixed by sextant angles, the horizontal distances being determined graphically or by computation. An apparent horizontal velocity determined between two buoy stations a sufficient distance apart is usually more reliable than a value based on distances depending on sextant fixes, because the distance involved is usually more accurately known in the former case.

### 635. DETERMINATION OF VELOCITY

An accurate knowledge of the velocity of sound in sea water is obviously of vital importance in R.A.R. and echo sounding, for without it accurate hydrographic surveys using these methods of position determination and depth measurement are impossible. Tables have been prepared from which the theoretical velocity at any depth may be determined if the temperature and salinity of the water at that depth are known (see **6343**). Theoretical velocities are entirely satisfactory for use in computing corrections to echo soundings, but for R.A.R. the path of the sound wave through the water must also be taken into account before accurate positions can be determined.

The path of the effective sound wave in R.A.R. varies with the character of the velocity gradient, as explained in **6231**, and at times and in many areas it is very difficult, if not impossible, to determine velocities satisfactory for accurate plotting unless the elapsed times are first corrected for the path of the sound wave. Because of the complicated nature of the problem, no entirely satisfactory method of doing this has as yet been devised. Regardless of the method used to plot R.A.R. distances on the smooth sheet, the hydrographer must realize that the elapsed times are greater, by an amount

varying with distance, depth of water, and character of velocity gradient, than they would be if the sound had traveled by a direct horizontal path. The apparent horizontal velocities needed for plotting are lower than the corresponding theoretical velocities, the difference generally increasing as the depths and the distances from the R.A.R. stations increase

### *6351. Apparent Horizontal Velocity From Tests*

Where apparent horizontal velocity is to be used in plotting, the values should be derived from distances slightly longer than the R.A.R. distances involved, if practicable. Under unfavorable conditions it may be necessary to determine apparent horizontal velocity for various distances from each R.A.R. station, using values varying with distance when plotting.

Apparent horizontal velocity tests should be made under carefully selected conditions. Where practicable, the temperature and salinity conditions should be normal for the period and area, and the depths should be average for the area. If the tests are made between two buoys, the distance between them should have been measured with taut wire and the tests should be made when there is a strong steady current to make the buoys lead approximately the same amount and direction from their respective anchors. A period of slack current should not be selected, for then the buoys may be leading in different directions, thus introducing an error into the horizontal distance between them. Where sextants are used to fix the positions of the bombs for tests, only strong fixes using accurately located shore stations should be used. A series of three to five bombs, each located in this manner by an independent sextant fix, should be used to obtain an average velocity for each distance for which tests are made. The sextant fix, with a check angle if possible, should be marked at the instant the bomb strikes the water and as near to this point as practicable; or the distance and bearing between the observation station and the point where the bomb strikes the water should be measured and allowed for in plotting or computing the position. Bombs used in tests should be of the same size as would be used at comparable distances in R.A.R. Results of tests that are in any way questionable should be rejected and not considered in computing the velocities. The distances from the bomb positions to the R.A.R. stations may be either computed, or scaled graphically on an accurate projection.

An excellent opportunity is afforded to determine the apparent horizontal velocity during a taut-wire measurement of the distance between two buoys, at least one of which is a sono-radio buoy. Test bombs should be fired at frequent and regular intervals, the taut-wire sheave being read at each bomb to determine an accurate distance to the R.A.R. station. Such a test discloses any variation in apparent horizontal velocity due to distance or depth, and the data obtained may be used to plot R.A.R., provided the tests are based on sufficiently long distances.

To correlate the apparent horizontal velocity with the theoretical velocity and to provide adequate data for studies of the propagation of sound in sea water, a serial temperature should be observed in the locality immediately before, or after, each test or series of tests. If the test is in conjunction with a taut-wire measurement, a serial temperature should be observed near one end before starting the measurement, another near the other end after the completion of the measurement, and if practicable, a third about halfway between, if the distance exceeds 10 miles.

### *6352. Frequency of Tests*

The number of apparent horizontal velocity tests required cannot be specified without a knowledge of the area. A minimum of one or two tests per month should suffice for areas where, and seasons when, temperature and salinity conditions are relatively stable. But where and when temperature and salinity are variable, more frequent tests will doubtless be needed to determine the velocity with the accuracy specified in **6313**.

The hydrographer should not be content with satisfying the minimum requirements where additional tests can be made in conjunction with other operations, without delaying the progress of the work. During taut-wire measurements apparent horizontal velocity tests should be made at every opportunity. Such tests should be distributed regionally as far as practicable throughout the project area and made at frequent intervals during the period of the survey. In buoy-controlled surveys tests should be made at every opportunity over distances that have been measured with taut wire.

### *6353. Indirect Measurement of Velocity*

Near the offshore limits of some R.A.R. surveys it may be difficult or impossible to determine the apparent horizontal velocity of sound from a known distance. It is also possible that appreciable errors may be introduced by plotting R.A.R. positions in such areas with an apparent horizontal velocity determined in the inshore areas, where the physical characteristics and the depths of the water may be quite different. An apparent horizontal velocity for use in such areas can be computed, if certain assumptions are made.

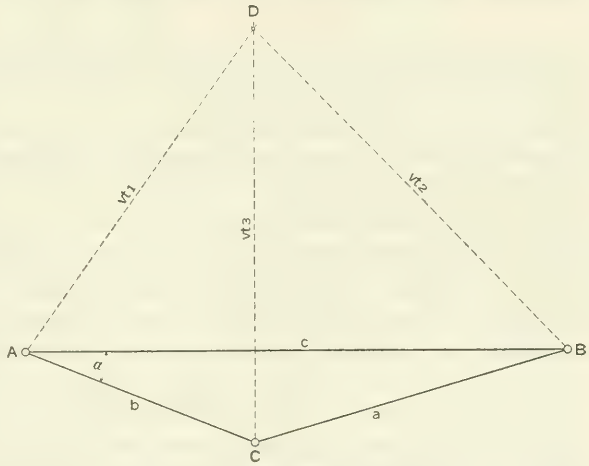


FIGURE 132.—Velocity of sound determined from time intervals simultaneously measured to three known stations.

Where elapsed times have been measured from a bomb position to three R.A.R. stations, assuming that the apparent horizontal velocity is the same over the three travel paths, the apparent horizontal velocity may be computed without any knowledge of the three distances. In figure 132, *A*, *B*, and *C* represent three R.A.R. stations, and *D* represents the position at which three elasped times are measured. The distances *a*, *b*, and *c* between the R.A.R. stations, as well as the angles of the triangle that they form, are known or may be computed. The distances *AD*, *BD*, and *CD* are unknown, but the corresponding elapsed times $t_1$, $t_2$, and $t_3$, required for a subaqueous sound wave to travel from position *D* to the three R.A.R. stations, are known. From these data the apparent horizontal velocity *v* may be computed from the following equation:

$$v^2t_1^2 = -q + \frac{2p\ (p+rs)}{1+s^2} \pm \frac{2p\sqrt{p^2+2prs-r^2-q-qs^2}}{1+s^2}$$

in which the terms $p$, $q$, $r$, and $s$, stated in known values with $\alpha$ equaling the angle $BAC$ (see fig. 132), are as follows:

$$p=\frac{c}{1-\left(\frac{t_2}{t_1}\right)^2}$$

$$q=\frac{c^2}{1-\left(\frac{t_2}{t_1}\right)^2}$$

$$r=\frac{c^2\left[1-\left(\frac{t_3}{t_1}\right)^2\right]-b^2\left[1-\left(\frac{t_2}{t_1}\right)^2\right]}{2b\left[1-\left(\frac{t_2}{t_1}\right)^2\right]\sin\alpha}$$

$$s=\frac{c\left[1-\left(\frac{t_3}{t_1}\right)^2\right]}{b\left[1-\left(\frac{t_2}{t_1}\right)^2\right]\sin\alpha}-\cot\alpha$$

In solving for $v$, the sign of the term to the right of the $\pm$ sign must be chosen to give an apparent horizontal velocity in approximate agreement with the estimated value. If the wrong sign is used, the error will be obvious, in most cases, from the value obtained.

It is obvious that there must be no doubt regarding the accuracy of the elapsed times used in the computation, and conditions of temperature, salinity, and depth should be similar along the three paths of travel; otherwise an erroneous value for the velocity of sound will result. Computations should be made for several different positions and if a reasonable check is obtained, the results should be averaged for use.

### *6354. Effect of Current on Velocity of Sound*

If sound travels through water which is moving as a mass, the velocity of sound will be increased or decreased by an amount depending on the velocity and direction of the movement. A current of 1 knot whose direction is the same as the propagation of sound, increases the apparent horizontal velocity of sound by a little more than 0.5 meter per second, and of course decreases it by an equal amount if the directions are opposite. Any other current will increase or decrease the velocity by an amount depending on the strength of the current and the relation between its direction and the direction of propagation. Ocean currents are generally of moderate strength so their effect on the velocity of sound is not large; furthermore, sufficient information is seldom available to correct for it; therefore the influence of current on the velocity of sound is usually disregarded in R.A.R.

The abnormal temperature and salinity conditions caused by turbulence near the edges of an ocean current, and in eddies generally, have a pronounced effect on the propagation of sound directed through them. The sound wave may be completely dispersed at such places, so that no sound is received beyond them. This effect has been repeatedly observed at the edge of the Gulf Stream in R.A.R. surveys off the South Atlantic Coast.

## 636. Methods of Applying Velocity Data

Corrections to echo soundings are computed from theoretical velocities based on depths, and average temperatures and salinities. The method of determining these corrections is explained in **561**.

For plotting R.A.R. positions, the effective horizontal velocity is required (see **63**), and this is more difficult to determine. Sound is rarely transmitted through sea water along a straight horizontal path—it is usually reflected and refracted depending on the velocity gradient (see **623**). The velocity of the sound wave at any instant is a function of the temperature, salinity, and depth of the water at that instant. In a heterogeneous medium, such as sea water, the velocity of the sound wave is continually changing as it is propagated forward. The velocity along the path of the wave is the mean of the different instantaneous velocities. But if this velocity were multiplied by the elapsed time interval measured, the distance obtained would be the length of the path of the wave, whereas what is required in R.A.R. is the horizontal distance. An arbitrary value of velocity must often be used, which when multiplied by the travel time of the sound wave will give the true horizontal distance between the bomb and the R.A.R. station. Such a velocity is termed an *apparent horizontal velocity.* To determine it for all conditions encountered in R.A.R. is not a simple matter, and empirical methods must often be used.

Where it is possible to determine an apparent horizontal velocity experimentally, by measuring the travel time of the sound wave over a known horizontal distance, such a velocity can be used if the distances and depths in the area being surveyed are similar to those where the tests were made, and the velocity gradient approximates the original. Otherwise a comparison of the apparent horizontal velocities with the computed theoretical velocities based on the physical characteristics of the water at the time of the tests must be used as a basis for correcting theoretical velocities (see **6343**). Sometimes theoretical velocities at selected depths will be found applicable.

A method is needed by which the elapsed times along the actual sound path may be readily corrected from a knowledge of the velocity gradient and the approximate depths, so that the corrected times may be used with mean computed velocities to plot R.A.R. distances. Until this problem has been satisfactorily solved, empirical methods such as the above must be used to determine velocities for use in plotting R.A.R. distances.

### *6361. General Procedure*

The velocities to be used in plotting any R.A.R. survey shall be determined as follows:

(1) The apparent horizontal velocity shall be accurately determined by tests, during which temperature, salinity, and depth measurements shall be made.

(2) Velocity-depth curves (see fig. 126) shall be drawn from the data on Form 717 (see **6343**), and the velocity gradients shall be studied to determine the most probable path of the sound wave for that season, not only along the track where the tests were made but throughout the area.

(3) The apparent horizontal velocities determined by test shall be compared with the corresponding theoretical velocities computed from the tables (see **6343**), to verify the probable path as determined in (2) above, and to determine for what depths to compute theoretical velocities and what arbitrary corrections, if any, to apply to them.

(4) Apparent horizontal velocities determined by test may be used for plotting where the temperatures and salinities vary only slightly from those observed at the time of the test, and for distances and in depths similar to those where the tests were made.

(5) Computed theoretical velocities, sometimes based on an arbitrarily chosen depth or arbitrarily corrected, shall be used to plot all R.A.R. for which (4) above does not apply (see **6362**).

### *6362. Specific Rules*

In connection with **6361**(5) it is necessary to determine whether to use theoretical velocities computed for an arbitrarily chosen depth; mean velocities from surface

to a certain depth, perhaps arbitrarily chosen; or one of these to which an arbitrary correction is applied based on apparent horizontal velocities experimentally determined. The cases that occur fall into five categories, depending on the type of velocity gradient. These categories are described below, together with the procedure to be followed. It is thus incumbent on the hydrographer to determine, in any given case, which procedure should be used.

Through a study of the velocity curves obtained (see **6361**(2)), the project area is divided into sections, if necessary, with characteristics as nearly uniform as the available information warrants. The category is next determined. If it is not obvious from the velocity curves and the text in (*a*) to (*e*), into which category a sectional area belongs, recourse must be had to the procedure in **6361**(3). Thus the final criterion by which procedure (*a*) to (*e*) is determined, is greatest practicable accuracy. The proper category is selected by applying the following rules to the apparent horizontal velocities determined by test.

(*a*) *Velocity nearly constant from surface to bottom.* The apparent horizontal velocity determined by test should almost equal the mean computed velocity from surface to bottom at the time and location of test. *Use mean computed velocity for plotting.* This condition is general in many ocean areas during the winter and early spring. For moderate distances the sound wave will follow practically a straight path from source to point of reception. Where the distance involved is long enough for the bottom to obstruct this path, because of the curvature of the earth, the first sound wave received will be one which has been reflected from the water surface—the reflection from the bottom being a later arrival. It is under these conditions that R.A.R. will function most favorably and at maximum distances. Any increase in the length of the path due to reflection of the sound wave will be so slight that the sound wave can be assumed to travel a horizontal path.

(*b*) *Velocity increases moderately from surface downward* to some depth at which it starts to decrease. The apparent horizontal velocity determined by test should almost equal the mean theoretical velocity at time of test from surface to the depth where the velocity starts to decrease. *Use mean computed velocity from surface to the depth where the velocity starts to decrease.* The path of the sound wave will be a succession of widely spaced reflections from the surface. The first sound impulse received will never have been reflected from the bottom. The increased length of the path of the sound wave will be so slight that error thus produced can be ignored and the sound wave can be assumed to travel a horizontal path. Where the R.A.R. distances are relatively short, the velocity based on the physical conditions at or near the surface may have to be used, rather than the mean velocity.

(*c*) *Velocity increases rapidly from surface downward* to some depth at which it starts to decrease. The apparent horizontal velocity determined by test should be less than the mean theoretical velocity at time of test computed from surface to the depth where the velocity starts to decrease. *Use mean computed velocity from surface to the depth where the velocity starts to decrease, corrected by the difference determined by test.* The sound wave is refracted sharply upward so that the path is a succession of relatively closely spaced reflections from the surface. The increase in the length of the path is too great to permit the use of mean computed velocity without correction. Furthermore, if the distance is long, the sound wave reflected from the surface may be attenuated so that it is never received, in which case the received sound wave is one reflected from the bottom. For this reason it may be preferable to use apparent horizontal velocity if a sufficient number of adequately distributed tests can be made.

(*d*) *Velocity decreases from the surface downward* to a depth at which it starts to increase. The apparent horizontal velocity determined by test should be appreciably less than the mean theoretical velocity at time of test computed for a section of water from surface to bottom. This type of velocity gradient is general during the summer months. *Use apparent horizontal velocity,* or *mean computed velocity from surface to bottom corrected by the difference determined by test.* Under such conditions the sound wave is refracted sharply downward through the upper layer of water if the decrease in velocity is rapid, and is reflected repeatedly between surface and bottom. The path of the sound wave is appreciably longer than the horizontal distance and uncorrected computed velocities cannot be used.

(*e*) *Velocity computed for a selected depth.* A comparison of the apparent horizontal velocity determined by test discloses that it is in consistent agreement with the velocity computed for a certain

depth. For areas and seasons where this is proved by test, *use the computed velocity for the selected depth.* The basis for this is that the increase in the length of the sound wave path is nearly compensated for by the difference between the mean computed velocity and the computed velocity at the selected depth. In certain areas where there are temperature reversals, it has been found that the depth at which a marked change in the temperature gradient occurs will give this agreement.

Data from R.A.R. surveys along the Pacific Coast and in Alaska, and for some areas on the Continental Shelf of the Atlantic Coast, indicate that for depths not exceeding 300 fathoms a very close empirical relationship exists between apparent horizontal velocity determined by test and *bottom velocity,* the latter being the average of the velocities computed for the bottom depths along the path. The velocity gradient in such cases will generally be found to fall in the (*d*) category. Where tests show that such relationship exists, the bottom velocity may be used to plot R.A.R. For depths greater than 300 fathoms, the velocity at 300 fathoms is used.

In order to obtain satisfactory results from R.A.R., the hydrographer must be familiar with the theory of sound propagation; only then will he be able to evaluate the results of tests made to determine apparent horizontal velocity, and to select the most practicable means of determining the correct velocities to use in plotting. In general, seasonal and regional changes of temperature and salinity require changes in the plotting velocity; other influences being constant, an increased depth generally requires a lower plotting velocity; and frequently different values must be used for different distances from R.A.R. stations.

Regardless of how velocity is used in plotting R.A.R., for the sake of simplicity and in order to eliminate some of the variables, average temperatures and salinities must be assumed to exist throughout an area surveyed during a limited period of time (see **5612**). For most areas the errors introduced by these assumptions will be slight. In some areas, however, there are large regional or seasonal changes of temperature and salinity and in these, the regions and periods of time must be limited to those during which one set of average conditions may be applied.

## 64. R.A.R. STATIONS

Three different types of receiving stations have been used by the Coast and Geodetic Survey in the R.A.R. method of control. In the chronological sequence in which they were developed they are; shore station, ship station, and sono-radio buoy. Sono-radio buoys have entirely taken the place of ship stations and have at least narrowly restricted the use of shore stations. Each type of station has certain advantages which make its use particularly advantageous under some conditions, but each has also certain disadvantages which limit its use.

### 641. SHORE R.A.R. STATIONS

The first R.A.R. stations were established on shore, and such stations may still be found advantageous where deep water extends close to the shore in areas where strong currents prevail. A shore station may be preferable to a sono-radio buoy in many localities on the Pacific Coast and in Alaska, but on the Atlantic Coast, where there are extensive areas of shoal water, their use is generally inexpedient. The selection of shore station sites, and the equipment and its installation are considered in **261**. Only the advantages and disadvantages are considered here.

Each shore station must have at least one radio technician to attend the station and at isolated localities two men are generally required. This increases the operating cost but affords several important advantages over an automatically operated station, such as a sono-radio buoy. The technician can adjust the sensitivity of the apparatus to obtain the best reception for the temporary conditions; he can usually repair any

breakdown of the apparatus; he can keep batteries charged and the station at maximum operating efficiency; and he can listen to the bomb signals as they are received and measure the amplitude of the sound. A knowledge of the relative strength of the bomb signal, radioed to the survey ship by the technician, is valuable in plotting and in determining the size of bombs to use.

A shore station tended by a radio technician will generally require less servicing from the survey ship than any other type of station, but in isolated localities the station must be supplied from the ship, even to the extent of drinking water.

Hydrophone sites for shore stations are generally difficult to select. Frequently the position of the hydrophone must be moved several times before it is where sound will be received from the desired directions. (See **2612***a*.)

Depending on the locality, from 1 to 3 days may be required to establish a shore station, and because a comparatively smooth sea is required to lay the cable, the establishment of a station on the open coast may frequently be delayed several weeks by bad weather or a heavy swell.

### 642. Ship R.A.R. Stations

The use of ship R.A.R. stations in extensive areas of comparatively shoal water was a necessary expedient before the automatic sono-radio buoy was developed, because the attenuation of the sound in such areas was so great that the sound would reach shore stations from only comparatively short distances offshore. The shore station equipment was installed on board ships and the ships were anchored where stations were needed, but their maintenance was exceedingly costly. Ship stations had all the important advantages of shore stations and in addition they were mobile. A station ship could be moved to a new position without delaying, and generally without interrupting, the operations of the survey ship. They are no longer used as R.A.R. stations. (See **262**.)

### 643. Sono-Radio Buoy Stations

The sono-radio buoy is a fully automatic subaqueous sound-receiving and radio-transmitting unit that may be used in most localities as an R.A.R. station. Using the Parkhurst anchor-detaching apparatus (see **2834** and **2851**), it is probable that a sono-radio buoy can be anchored in any depth of water; consequently accurately controlled hydrographic surveys can be made in any oceanic area (see **25**). However, because it is unattended, a sono-radio buoy has a somewhat shorter effective range than a shore station has.

The sono-radio buoy was developed to eliminate two of the then most objectionable features of R.A.R.—the use of expensive ship stations along the Atlantic Coast, and the difficulty of laying cable through the surf in establishing shore stations on the Pacific Coast and in Alaska. A number of buoys can be operated at the cost of operating one shore station.

Where strong currents prevail there is some difficulty in maintaining a buoy in a nearly upright position. Occasionally the anchoring gear fails, resulting in the loss of the sono-radio buoy, or at least the position.

Several types of sono-radio buoys are used by the Coast and Geodetic Survey. The different types have resulted from the efforts of individual experimenters to develop a sono-radio buoy best suited to overcome the particular conditions found in the waters being surveyed. The physical construction of sono-radio buoy structures

is described in **284**. The electric circuits of the several types of sono-radio buoys are very similar in many respects, and the distance performance is about the same for all of them. Two of the types in most general use are described in **651** and **652**, and their features are compared in **653**.

The principal parts of the electric equipment of a sono-radio buoy are the audio amplifier, the keying circuit, and the radio transmitter. The primary purpose of the audio amplifier is to amplify the small voltage, created across the terminals of the hydrophone by the bomb signal, sufficiently to operate the keying circuit. The keying circuit then sets the radio transmitter into operation. The general requirements of these three component parts are described in **6431**, **6432**, and **6433**.

### *6431. Audio Amplifier*

The gain of the audio system must be sufficient to provide the required sensitivity—experience has indicated that a gain of 80 to 90 decibels is more than ample, and much less than this is used in practice. The values are for measurements between the input of the hydrophone and the keying circuit. The gain needed in the amplifier depends somewhat on the sensitivity of the hydrophone used, and the amount of gain that can be used is limited by the unwanted noises entering by way of the hydrophone. Consequently the latter also limits the distance range of the sono-radio buoy. Means should therefore be taken to reduce spurious noises to a minimum and thereby increase the bomb-to-noise ratio—proper suspension of the hydrophone, as described in **656**, will aid in this respect.

The gain of the amplifier must be maintained at a nearly constant value while the sono-radio buoy is on station. Tests have proved that the gain can be maintained within 2 decibels of the original value for at least 1 month of operation. Tubes should be used that retain fairly constant operating characteristics with reasonable changes of voltage. Voltage and current regulators may be used to good advantage in maintaining the gain of the amplifier at a constant value. The circuits of the sono-radio buoys are arranged so that the decay of the **B** and **C** batteries has a compensating effect on the amplifier gain, with almost no net change.

Within limits, amplitude and frequency distortion may be disregarded in the design of the amplifier. It is not necessary to have the gain of the amplifier flat in frequency nor is it necessary to amplify frequencies much above 300 cycles. In fact, in some cases it has been found advantageous to have the amplifier peaked for a certain frequency range. To conserve the **B** batteries, the amplifier tubes should be biased close to the cut-off point. This will naturally result in amplitude distortion, but this can be tolerated in R.A.R., since it is not necessary to reproduce and transmit the characteristics of the bomb sound with fidelity—the essential requirement is that the *first* bomb signal actuates the radio transmitter immediately on arrival at the hydrophone.

One of the primary requirements of the amplifier is that it be stable. Tendencies toward regeneration or degeneration cannot be tolerated because unpredictable operation would be introduced, and different results would be obtained from different sono-radio buoys of the same type; and, in addition, a variable time lag would be introduced to lessen the accuracy of R.A.R. distance measurements. Time lag is inherent in all audio-frequency amplifiers to varying degrees, but the component parts of the amplifier must be selected and arranged in such a manner that this lag will be small and relatively constant.

### *6432. Keying Circuit*

The purpose of the keying circuit is to cause the radio transmitter to operate when the bomb signal arrives at the sono-radio buoy. The keying circuit is actuated by the output energy of the audio amplifier. It should be designed to have a threshold of operation, so that spurious sounds of low amplitude will not operate the radio transmitter, but so that, when a bomb signal of sufficient strength is received, the transmitter is operated at nearly full-power output. But the operating threshold must not be so high as to preclude operation by weak bomb signals. Normally the wave front of the bomb signal is sufficiently steep to make the lag, due to the threshold, negligibly small. The keying circuit must be designed with a view to keeping the time lag at a low and constant value. For use in R.A.R., it has generally been found desirable to have the keying circuit actuate the transmitter so that the signal will be an unmodulated pulse of nearly constant amplitude. However, some sono-radio buoys have been used by the Coast and Geodetic Survey in which the bomb signal modulates the radio transmitter. Undistorted modulation is not attempted.

Under certain conditions the bomb signal received at the hydrophone may be prolonged as much as 7 seconds or more, and in such cases it is advantageous to limit the length of the radio signal to a shorter time interval. Such prolonged bomb signals are due to the numerous reflection paths of the sound between the source of the bomb explosion and the hydrophone (see fig. 123). Also, when the bomb explodes close to the hydrophone, reverberation lasting several seconds may occur. The disadvantage of long radio signals is the interference that occurs between two or more signals from two or more sono-radio buoys at nearly equal distances from the survey ship, the signal from the nearest blanketing those transmitted immediately afterward. In practice, the radio signals have been made as short as 0.12 second, for use where such interference occurred frequently; as, for example, where the sounding lines were near bisectrices (see **6814**). For ordinary use, a signal from 0.25 to 0.5 second in length has been found desirable. The method of signal shortening usually makes the sono-radio buoy inactive for 3 to 5 seconds after the radio signal has been cut off. The advantage of keeping a sono-radio buoy inactive for a short time after transmission is that interference with survey operations from other buoys is in this way prevented. Otherwise, faulty operation of the circuits, spurious noises caused by passing ships, or by other causes, could keep the transmitter circuit in continuous operation for long periods, or until serviced. Sono-radio buoys equipped with silencing circuits when subjected to undesired noise will transmit interrupted signals of short and evenly spaced duration, which, though annoying, does not entirely prevent the use of the other sono-radio buoys in the same vicinity.

There are certain disadvantages in the use of signal-shortening-and-silencing circuits. When all the radio signals transmitted are of uniform length, signals caused by bombs cannot be distinguished from those caused by water noises. Furthermore, if the sono-radio buoy is actuated just before the bomb signal arrives, the silencing circuit prevents the bomb signal from operating it. Therefore, where prolonged signals are not particularly bothersome shortening-and-silencing circuits are not incorporated in the sono-radio buoy. The operation of these circuits is considered in **6522**.

### *6433. Radio Transmitter*

The signal of the radio-frequency transmitter used in sono-radio buoys must be relatively constant in frequency. The frequency should be as constant as can be

obtained from a quartz crystal with a low temperature coefficient, but temperature control is not necessary. The frequencies of all the sono-radio buoys used in a scheme of control need not be exactly the same—in fact, small differences of a few hundred cycles in frequency aid in distinguishing one sono-radio buoy from another.

Under normal operating conditions, at a wave length of about 72 meters (4160 kc), 3 watts of radio-frequency power will furnish a signal of adequate strength to cover the distance range desired of a sono-radio buoy—the maximum range required in most surveys being about 100 nautical miles (see also **6443**).

The transmitter may be of conventional design—either a crystal-controlled oscillator driving a class C amplifier or a single-tube crystal-controlled oscillator has been found satisfactory. Both of these types are used by the Coast and Geodetic Survey to good advantage (see **6513** and **6523**).

For convenience, the transmitter should be designed so that once it is properly tuned it will not require retuning for a long time. This applies principally to the equipment in the drum. Any slight adjustment to the tuning of the output circuit, or to the antenna-coupling circuit, can be readily made.

Where the length of the antenna is only a small fraction of the radio wave length, the base of the antenna is at a high impedance point and must be elevated above the water surface to prevent it from being effectively shorted during rough weather. This makes it necessary to couple the transmitter to the antenna through a low-impedance waterproof transmission line. This may be a two-conductor rubber-covered cable. The transmission line is terminated in a watertight container mounted on the buoy structure about 3 feet above the water, which contains the antenna-coupling circuit.

It is desirable to make the vertical antenna as long as practicable, consistent with convenient handling on the ship. The ideal length of antenna would be about a quarter wave length, but of course this is impracticable for a frequency of 4 megacycles. Sono-radio buoys, used by the Coast and Geodetic Survey, operate on a wave length of 72 meters, but their antennas are generally not more than 18 feet long. An 18-foot antenna represents about one-thirteenth of the wave length.

## 644. Radio Frequencies and Power

### *6441. Radio Frequencies*

The most suitable frequency for radio transmission of R.A.R. stations requires some consideration. The ideal frequency would be one at which reliable radio signals could be received without interference 24 hours a day in all seasons at all necessary operating distances. However, since available power is limited and due to the varying distance to which small amounts of radio energy will produce satisfactory signals, the ideal frequency is generally unattainable.

Except for some slight directivity of the ordinary antennas used in R.A.R., the radio waves are transmitted in all directions of radii of a hemisphere drawn about the antenna as a center. Radio waves starting from the antenna at zero angle with the earth's surface are called ground waves and all others are called sky waves. The ground wave follows the curvature of the earth and the distance to which it is propagated is a function of the conductivity of the earth's surface. Fortunately for hydrographic surveying, the conductivity of sea water is much greater than that of the land and consequently the ground wave travels much farther over the sea than over land. Except for slight refraction and diffraction a sky wave travels in a straight line until

reflected from the ionosphere, which is a layer of ionized gas from 50 to 150 miles above the earth. The ionosphere is slightly conductive and its characteristics vary during the 24 hours and with seasons and sun spots. The propagation of radiation from low-frequency transmitters is principally by the ground wave and less by the sky wave, but the ground wave of the higher frequencies does not travel far and reception of such frequencies is by a sky wave through an optical path, or by way of one or more reflections from the ionosphere at distances of thousands of miles. Since there is almost no change in the ground wave and many complicated changes in the sky wave, it is apparent that propagation by the ground wave is much more uniform than by the sky wave. For this reason, it is desirable to select a frequency whose ground wave extends as far as required for R.A.R. operations and which is still high enough to require little power. Frequencies between 2000 kc and 5000 kc, transmitted with a power of 5 watts, may be received from 150 to 250 miles via the ground wave. However, the radio signal must not only be heard but it must also be recorded on a chronograph tape.

It is fairly easy to read radio signals through radio interference on nearly the same frequency, but the chronograph is unable to make this distinction. For this reason, the desired radio signal should be stronger than the others and there should be as little interference as possible. Interference can be divided into two broad classes: static and communication. Static interference can be subdivided into atmospheric, caused by electric disturbances in the air such as lightning, and man-made static caused by electric apparatus, sparking commutators, loose connections, etc. At frequencies above 2000 kc, atmospheric interference decreases, but man-made interference increases. Man-made interference is controllable to a considerable degree and can be eliminated on a survey vessel by the use of proper filters in connection with the offending apparatus. It might be inferred that the lesser atmospheric interference at higher frequencies would make the use of these frequencies desirable for R.A.R., but the advantage to be gained in this respect would be more than offset by the unreliable propagation at the higher frequencies, although it must be stated that higher frequencies have not yet actually been tried in R.A.R.

Communication interference can be avoided only by using frequencies for R.A.R. which are reasonably free from such interference. Since the frequencies that can be used for R.A.R. are assigned by the Federal Government, and quite often are shared with other radio stations, it is difficult to avoid this type of interference completely.

### *6442. Authorized Radio Frequencies*

The frequencies (in kilocycles) authorized by the Federal Communications Commission for use by the Coast and Geodetic Survey for R.A.R. and communications are:

| | | | | | |
|---|---|---|---|---|---|
| 1,738 | 2,492 | 4,135 | 8,270 | 12,405 | 16,540 |
| 1,742 | 2,496 | 4,160 | 8,320 | 12,480 | 16,640 |
| 1,746 | 2,500 | | | | |

Those frequencies that are available to all vessels for communication have not been tabulated.

Of the above frequencies, 4,135 and 4,160 kc are most frequently used for R.A.R.; 2,492, 2,496, and 2,500 kc are also used, but less frequently. All these frequencies are shared with other radio stations. The frequencies available for use in R.A.R. should be monitored for a few days to select the one with the least communication interference in the area at the time its use is desired.

### *6443. Radio Power*

The minimum radio power that can be expected to give satisfactory signals at all R.A.R. distances is about 3 watts. This amount of power is adequate during daylight, except during periods of excessive interference. It may be inadequate for satisfactory R.A.R. operation at night, because, in some regions, atmospheric interference increases and the sky-wave signals are weaker during part of the period between sunset and sunrise.

The radio-frequency power output of the sono-radio buoys used by the Coast and Geodetic Survey is from 3 to 26 watts. Most of the shore-station installations have a radio-frequency power of from 10 to 100 watts.

## 65. SONO-RADIO BUOYS

### 651. VINCENT SONO-RADIO BUOY

The Vincent sono-radio buoy, used principally on the West Coast, utilizes electric equipment originally designed for use at R.A.R. shore stations. This equipment was adapted for use in sono-radio buoys by only minor alterations to the circuits and by substituting types of tubes requiring less filament power.

This sono-radio buoy has performed reliably for periods of more than 3 months, during which time neither servicing nor adjustments were necessary. Where the acoustic conditions of the water, the configuration of the bottom, and radio propagation are favorable, reliable operation can be expected from the sono-radio buoy at distances as great as 100 nautical miles or more.

The audio amplifier and radio-frequency equipment are all housed in a 12- by 7- by 7-inch metal box, which has a hinged top and a removable subchassis. This box and the necessary batteries for operation of the electric equipment are all secured inside the buoy drum—the batteries in the bottom—by means of a wood framework. Cables, connecting the equipment in the drum to the antenna and the hydrophone circuits, pass through stuffing boxes in the cover of the drum. The buoy structure is described in **2842**.

The circuit diagram of this instrument is shown in figure 133. Either a Vincent hydrophone (**6563**) or a Dorsey hydrophone (**6561**) is used with this sono-radio buoy. The other electric equipment—the audio amplifier, the keying circuit, and the radio-frequency equipment—is described in **6511**, **6512**, and **6513**.

### *6511. Audio Amplifier*

The audio amplifier is composed of two transformer-coupled tubes. A hydrophone unit with an impedance of 900 ohms is usually used, requiring an impedance-matching transformer to match this unit to the grid of the first amplifier tube. The two tubes of the amplifier are pentodes, type 1A5, with a 1.4-volt filament. The first tube is coupled to the second by means of a transformer designed to operate from a tube of high plate impedance. This is a 1:2 transformer with a primary inductance of 600 henries. The second tube supplies the energy to operate the keying circuit, being coupled to it by means of a transformer identical to that used with the first tube. This amplifier is broadly resonant at low frequencies, the necessary tuning being obtained by paralleling condensers across the primaries of the coupling transformers. The gain is about 90 decibels, which is sufficient to give a reasonable margin of sensitivity.

Decoupling circuits are used in the **B** and **C** battery supply leads to prevent regenerative effects. The amplifier gain is controlled by a variable potentiometer across part of the C battery, varying the amount of voltage to the grid of the first amplifier tube. A metering jack is provided by which the

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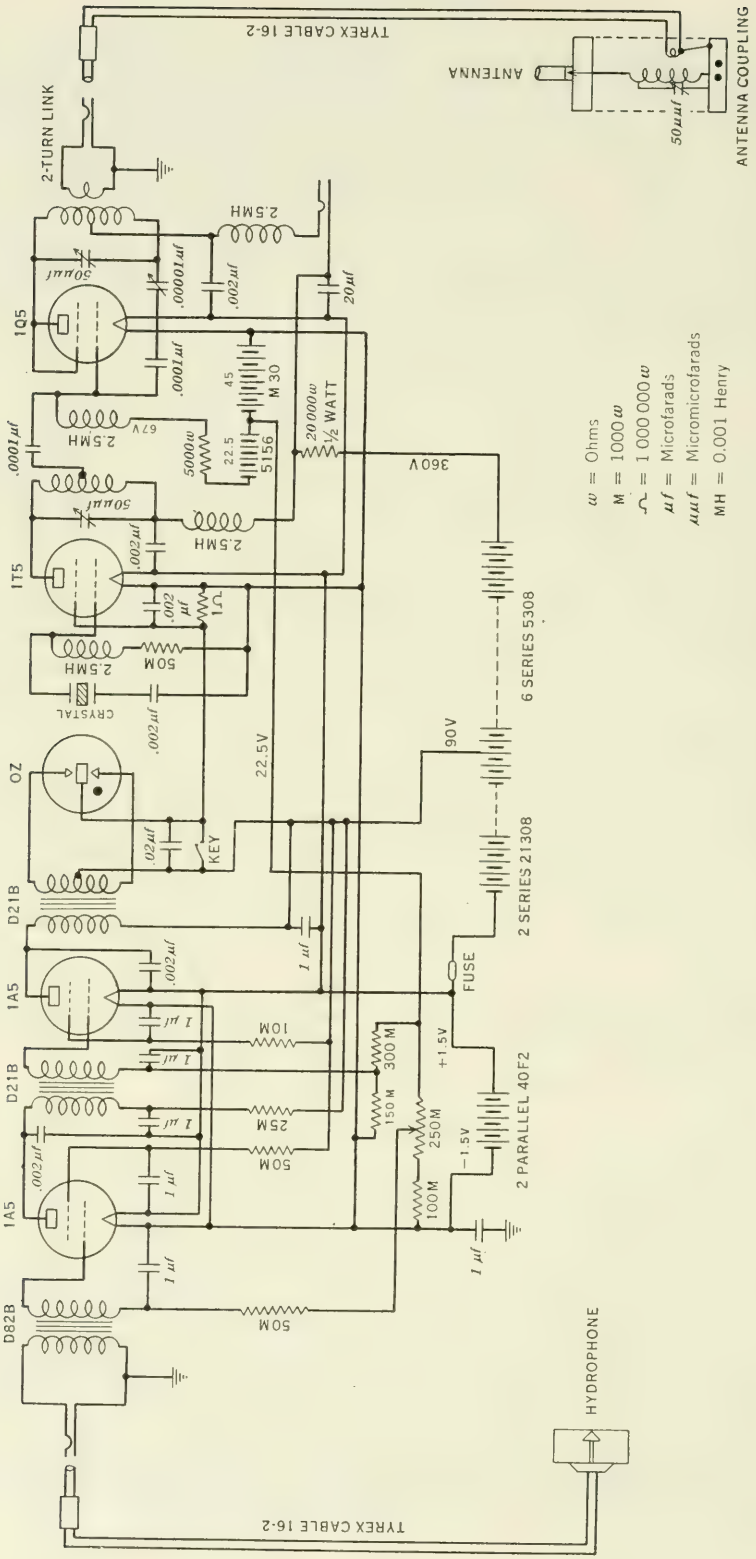


FIGURE 133.—Circuit diagram of Vincent sono-radio buoy

plate current to the radio-frequency amplifier may be measured. A switch is located in the filament and plate-supply leads for turning on or off all the electric equipment. A key is provided by which the transmitter can be turned on for tuning and testing purposes.

### *6512. Keying Circuit*

Following the audio amplifier is the keying circuit, its purpose being to turn on the radio-frequency transmitter at receipt of a bomb signal. The keying tube is a cold cathode gas-filled type *OZ*, installed so that its anodes are connected across the secondary of the output transformer of the audio amplifier, similar to a push-pull arrangement. The cathode is connected to the screen grid of the crystal-controlled radio-frequency oscillator. A d-c potential of 90 volts is applied to the anodes of the type *OZ* tube through the center tap of the output transformer. When a bomb signal is received and amplified the voltage created between the anode and cathode of the keying tube is sufficient to cause this tube to ionize and thereby conduct current, which applies a positive potential to the screen of the oscillator tube, which at once starts to function. Because of the push-pull arrangement, full-wave rectification occurs, adding to the efficiency of the keying circuit.

### *6513. Radio Transmitter*

The radio transmitter is a crystal-controlled oscillator furnishing driving power to a class C amplifier. The oscillator tube is a pentode type 1*T*5 whose frequency is controlled by means of a quartz crystal. This quartz crystal is a low temperature coefficient type, capable of maintaining the frequency of the transmitter within one part per million per degree centigrade from 20° C. to 50° C. The crystal is clamped in its holder so that it can be operated in any position. The holder is the so-called Navy-type, composed of a cylindrical glazed isolantite body and a metal base on which the crystal rests. The upper electrode is circular in shape and separated from the crystal by a small air gap. This electrode is adjustable so that the length of the air gap can be changed. Various frequencies that are assigned to the Coast and Geodetic Survey in the range from 2492 to 4160 kc are used.

The plate circuit of the oscillator is tuned, and connected to the power amplifier by capacitance inductance coupling. The power amplifier tube is a 1*Q*5 power-amplifier pentode, operating at the same frequency as the oscillator, which therefore requires neutralizing to prevent oscillations.

The transmitter is capable of delivering a radio-frequency power output of about 26 watts for a very short period. This power output is sufficient for reasonably reliable R.A.R. operation even where interference and static are prevalent. The high power output requires the use of a high plate potential on the transmitting tubes. A resistance capacitance circuit in the plate-supply lead of the radio-frequency oscillator and amplifier prevents high currents of long duration from damaging the transmitter tubes. Before the transmitter is operated by a bomb signal the electrolitic condenser, connected between the transmitter plate-supply lead and one side of the filaments, is charged to 360 volts or more. When the transmitter operates, this condenser discharges into the oscillator and amplifier tubes, the 20,000-ohm resistance through which the condenser was charged limiting the transmitter plate current to a safe value. With this arrangement the first and useful part of the radio signal will be of high amplitude. In addition, the resistance-capacitance combination limits the length of the radio signal. The advantage of this signal shortening is described in **6432**. The power amplifier and the antenna transmission line are coupled by means of link coupling. The transmission line connecting the transmitter to the antenna circuit is a waterproof two-conductor cable about 4 feet long which enters the drum and the antenna-coupling housing through stuffing boxes. The housing for the impedance-matching circuit of the antenna coupler and the antenna are described in **2842**(A).

### *6514. Batteries*

The electric energy to operate the sono-radio buoy is derived from dry batteries. Burgess batteries are used, and the type numbers are given on the circuit diagram, figure 133. The batteries occupy a volume of 2,292 cubic inches, and weigh 109 pounds. Connections between the batteries and the rest of the equipment are made by plug-in cables.

The total amount of filament current required by the instrument is 0.25 ampere. The quiescent plate current consumption of all the circuits is about 2 milliamperes. The total current is 90 milliamperes (peak meter reading) for the radio transmitter, when the instrument is operated by a bomb signal.

### *6515. List of Electric Equipment—Vincent Sono-Radio Buoy*

[The total cost of the electric equipment is about $150 based on 1940 prices. The antenna-coupling housing, antenna, antenna guys, and insulators are listed in 2842(B).]

| *Description* | *Size* | *Number required* |
|---|---|---|
| Resistor | 5,000 ohm ½ watt | 1 |
| Do | 10,000 ohm ½ watt | 1 |
| Do | 20,000 ohm ½ watt | 1 |
| Do | 25,000 ohm ½ watt | 1 |
| Resistors | 50,000 ohm ½ watt | 3 |
| Resistor | 100,000 ohm ½ watt | 1 |
| Do | 150,000 ohm ½ watt | 1 |
| Do | 300,000 ohm ½ watt | 1 |
| Do | 1,000,000 ohm ½ watt | 1 |
| Resistor, variable potentiometer | 250,000 ohm | 1 |
| Condensers, mica | 0.0001 mfd | 2 |
| Do | 0.002 mfd | 6 |
| Condenser, mica | 0.02 mfd | 1 |
| Condensers, paper | 1.0 mfd | 6 |
| Condenser, electrolitic, Sprague *UT*20 | 20.0 mfd | 1 |
| Condenser, variable | 10 mmfd | 1 |
| Condensers, variable | 50 mmfd | 3 |
| Sockets | Octal type (8-pin) | 6 |
| Do | 4-pin | 2 |
| Transformer, Amertran *D82B* | Line to grid | 1 |
| Transformers, Amertran *D21B* | Interstage | 2 |
| Chokes | 2.5 millihenries | 4 |
| Tubes, Raytheon | Type 1*A*5 | 2 |
| Tube, Raytheon | Type 1*T*5 | 1 |
| Do | Type 1*Q*5 | 1 |
| Do | Type *OZ* | 1 |
| Batteries, Burgess 40*F*2 | **A** batteries 3-volt | 2 |
| Batteries, Burgess 21308 | **B** batteries 45-volt | 2 |
| Batteries, Burgess 5308 | **B** batteries 45-volt | 6 |
| Battery, Burgess *M*30 | **C** battery 45-volt | 1 |
| Battery, Burgess 5156 | **C** Battery 22½-volt | 1 |
| Crystal and holder | Navy type (see **6513**) | 1 |
| Hydrophone | (See **6563**) | 1 |
| Cable connector, for batteries | Male type 8-prong | 1 |
| Cable connectors, for hydrophone and antenna | Male type 4-prong | 2 |
| Cable, multicolored | 8-conductor | 5 ft. |
| Cable, Tyrex Simplex, type *SJ*, 1/32″ insulation | 2-conductor No. 16 | 65 ft. |
| Stuffing tubes for above cable | | 3 |
| Tubing, Bakelite | 3 by 1½ inches | 3 |
| Wire, solid copper, enameled | No. 22 | 50 ft. |
| Metal box, for housing equipment | 12 by 7 by 7 inches | 1 |
| Miscellaneous | Screws, bolts, lumber, wire, solder, solder, lugs, and fittings. | |

## 652. East Coast Sono-Radio Buoy

The East Coast sono-radio buoy has evolved by improvements and simplifications from the earliest model. Figure 134 is the circuit diagram of this instrument; the buoy structure is described in **2841**.

The audio amplifier and radio-frequency transmitter are assembled on two 8- by 10- by 3/16-inch parallel pieces of Bakelite separated 5½ inches by four brass pillars, one at each corner. All the component parts of the audio amplifier and radio-frequency transmitter are on the bottom Bakelite plate, the top plate containing the gain control and test circuits. This assembly is secured to the inside of the drum cover by means of four brass posts that fasten to the top Bakelite plate. The control and test circuits can be reached by unscrewing a handhole cover in the lid of the drum. Connections to the hydrophone and antenna circuits are made by means of cables passing through

stuffing boxes in the flanged top of the drum. The batteries are contained in a wooden frame which is secured in the bottom of the drum.

The Dorsey hydrophone is used with this sono-radio buoy. This hydrophone and the method of supporting it are described in **6561** and **6562**. The hydrophone is coupled to the first tube of the audio amplifier by means of a line-to-grid transformer, selected to match the impedance of the hydrophone used.

### *6521. Audio Amplifier*

The audio amplifier consists of two stages; the first stage employs a type 32 screen-grid tube acting as a voltage amplifier, which is impedance-coupled to the second tube by means of an inductance-capacitance-resistance combination. The second tube is a high *mu* duplex-diode triode of which only the triode part is used. The plate circuit of this tube is coupled to the keying circuit by means of a 1:3 transformer. A step-by-step gain-control attenuator forms part of the coupling circuit between the first and second tube, arranged so that the amplifier sensitivity may be changed by intervals of 2 decibels. The full range of this attenuator is 20 decibels, permitting variations of gain from 65 decibels to the amplifier's maximum gain of approximately 85 decibels. No attempt is made to tune the amplifier, but the characteristics of the inductance and capacitance parts of the circuit are such that frequencies below 1000 cycles are favored.

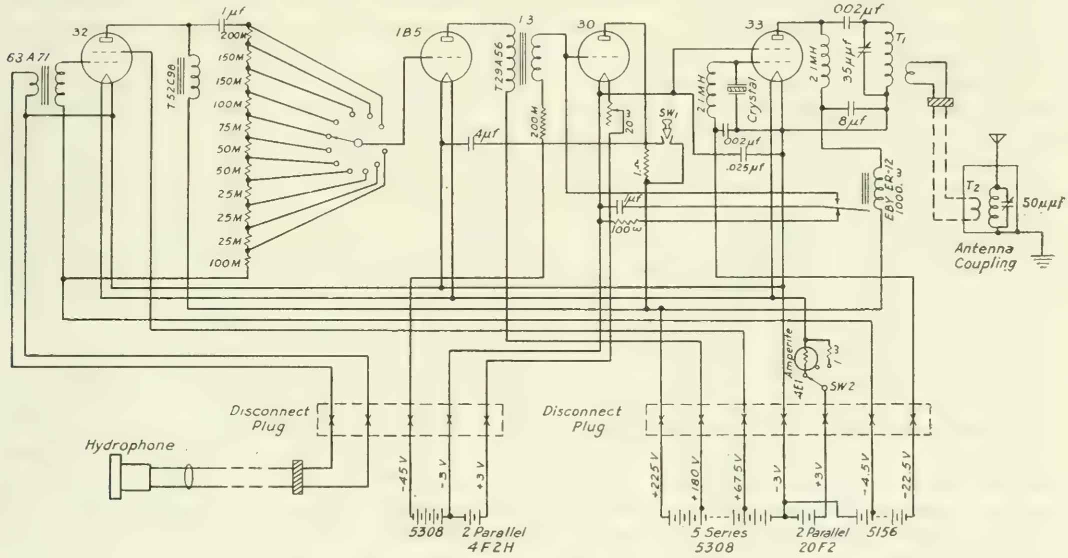


FIGURE 134.—Circuit diagram of East Coast sono-radio buoy.

### *6522. Keying Circuits*

A type 30 tube acts as the keying device to operate the radio transmitter. This tube is biased to beyond cutoff so that when there is no bomb signal there is no conduction through the tube, and the radio transmitter cannot operate. When a bomb signal actuates the keying tube, current flows through the tube and makes the screen of the radio-frequency oscillator positive, and oscillations commence almost instantly. This type of circuit requires a connection between the filament of the keying tube and the screen grid of the oscillator, therefore the keying tube must have separate filament and bias batteries which are well insulated above ground.

Associated with the keying circuit are two other circuits, one for shortening the radio signal regardless of the length of the bomb signal, and a second circuit to silence the sono-radio buoy for a period of a few seconds after the radio signal has been transmitted. The signal-shortening circuit is

composed of a relay in series with the plate-supply lead of the oscillator, so that when a bomb signal is received the oscillator tube draws plate current and the relay is operated, the contacts of which short the grid of the keying tube to the filament through a 1-microfarad condenser, thus stopping the operation of the keying tube and hence the oscillator. The length of the radio signal is only about 0.12 second. The silencing circuit consists of a 1-megohm 4-microfarad resistance-capacitance arrangement in the plate circuit of the keying tube. The condenser is normally charged to the same voltage as the **B** battery, but when the bomb signal is received the condenser discharges into the keying tube. A period of a few seconds is required to recharge this condenser through the 1-megohm resistor and during this period the sono-radio buoy is inactive. Not all types of East Coast sono-radio buoys employ the signal-shortening-and-silencing circuits for reasons discussed in **6432**.

### *6523. Radio Transmitter*

The radio-frequency power is generated by a type 33 power pentode, arranged in a conventional crystal-controlled oscillator circuit. The transmitter frequency normally used with this sono-radio buoy is either 4135 or 4160 kilocycles. The crystal is described in **6513**. The power output of the transmitter is about 3 watts. The antenna transmission line is a two-conductor rubber-covered Tyrex cable about 4 feet long which is link-coupled to both the oscillator circuit and the antenna coil. The housing for the antenna-matching circuit is a cast brass cylinder open at only one end onto which a cap screws. All the electric circuits are attached to this screw-on cap, and the two stuffing boxes for the antenna lead and the transmission line pass through it. It also contains a threaded hole through which the antenna tuning condenser can be adjusted, which is normally closed by a standard ¼-inch pipe plug.

The antenna is 18 feet long, made of hard-drawn copper tubing with a ⅜-inch outside diameter. The antenna is supported along the narrow edge of the centerpole of the buoy structure, and insulated from it at 2½-foot intervals by means of insulators of the house bracket type.

The controls mentioned in **652** that can be reached through the handhole in the lid of the drum are to permit adjusting and testing the circuits without opening the drum. There are four controls and two metering jacks grouped under the handhole opening. Two of the controls operate selector switches, the third is a push button, and the fourth is a rheostat control. One of the selector switches is a 3-gang 11-position nonshorting type of switch. Its functions are to control the amplifier gain by steps, to measure the filament, grid, and plate voltages of all tubes, and to turn on the radio transmitter for tuning and testing purposes. Only the gain control part of this switch is shown in figure 134. A suitable meter is plugged into the metering jacks to measure the voltages. The second selector switch is to select between an Amperite 4*E*1 voltage-regulator tube and a fixed 1-ohm resistor in series with the filament supply lead to the amplifier and oscillator. The regulator tube functions for several weeks after a new filament battery has been installed, but after this period the battery voltage drops below the control range of the regulator, and the 1-ohm resistance is then switched into the circuit in order to extend the life of the battery. This switch is also used to turn off the filament voltage. The push button is used only when testing or tuning the radio transmitter. Its function is to short out the 1-megohm resistor of the silencing circuit. The rheostat control is for adjusting the filament voltage of the keying tube.

### *6524. Batteries*

Nine Burgess dry batteries supply the energy for operating the sono-radio buoy; their type numbers are given in the circuit diagram, figure 134. The battery assembly weighs 53.5 pounds, exclusive of the battery case. The total volume occupied by the batteries is approximately 1,147 cubic inches.

The total filament current consumption of the amplifier and radio transmitter is 0.38 ampere, and the filament current of the keying tube is 0.06 ampere. The quiescent plate current consumption of all circuits is about 2 milliamperes, becoming about 40 milliamperes when the instrument is operated by a bomb signal.

One set of batteries and tubes can be expected to provide, on the average, for 30 to 40 days continuous use of this type of sono-radio buoy.

## *6525. List of Electric Equipment—East Coast Sono-Radio Buoy*

[The total cost of the listed material is about $150 based on 1940 prices. The material for the construction of the wooden buoy structure in which the East Coast equipment is normally used is listed in 2841 (B).]

| *Description* | *Size* | *Number required* |
|---|---|---|
| Resistor, I.R.C., *BT*–1 | 1 ohm 1 watt | 1 |
| Resistor, I.R.C., *BT*–½ | 100 ohm ½ watt | 1 |
| Resistors, I.R.C., *BT*–½ | 25,000 ohm ½ watt | 3 |
| Resistors, I.R.C., *BT*–½ | 50,000 ohm ½ watt | 2 |
| Resistor, I.R.C., *BT*–½ | 75,000 ohm ½ watt | 1 |
| Resistors, I.R.C., *BT*–½ | 100,000 ohm ½ watt | 2 |
| Resistors, I.R.C., *BT*–½ | 150,000 ohm ½ watt | 2 |
| Resistors, I.R.C., *BT*–½ | 200,000 ohm ½ watt | 2 |
| Resistor, I.R.C., *BT*–½ | 1,000,000 ohm ½ watt | 1 |
| Rheostat, Yaxley *C20R* | 20 ohm | 1 |
| Condensers, mica, Cornell-Dubilier 3*L* | 0.002 mfd | 2 |
| Condenser, paper tubular, Cornell-Dubilier *DT*–4*S*25 | 0.025 mfd | 1 |
| Condenser, paper tubular, Cornell-Dubilier *DT*–4*P*1 | 0.1 mfd | 1 |
| Condenser, paper tubular, Cornell-Dubilier *DT*–4*W*1 | 1.0 mfd | 1 |
| Condensers, paper, Western Electric 137–A | 4.0 mfd | 3 |
| Condenser, variable, Hammerlund *MC*–35–*S* | 35 mmfd | 1 |
| Condenser, variable, Hammerlund *MC*–50–*M* | 50 mmfd | 1 |
| Switch, nonshorting, Yaxley 1331 | 3-gang 11-position | 1 |
| Switch, Centralab 1461 | Single pole 3-position | 1 |
| Pin jacks, Yaxley 407 | One red and one black | 2 |
| Relay, single-pole double-throw, Eby *ER*–12 | 1,000 ohms | 1 |
| Sockets, Eby 12*A* | 4-pin | 3 |
| Socket, Eby 12*B* | 5-pin | 1 |
| Socket, Eby 12*C* | 6-pin | 1 |
| Socket, Amphenol *RS*5 | 5-pin | 1 |
| Socket, Amphenol *RS7S* | 7-pin | 1 |
| Cable connector, Amphenol *PM*5 | 5-prong (male) | 1 |
| Cable connector, Amphenol *PM*7 | 7-prong (male) | 1 |
| Transformer, Thordarson 29*A*156 | 3:1 interstage | 1 |
| Transformer, Thordarson 63*A*171 | Line to grid | 1 |
| Choke, Thordarson 52*C*98 | 1,080 henries | 1 |
| Chokes, Hammerlund *CH–X* | 2.1 millihenries | 2 |
| Crystal and holder | Navy type (see 6513) | 1 |
| Tube, R.C.A. | Type 30 | 1 |
| Do | Type 32 | 1 |
| Do | Type 33 | 1 |
| Do | Type 1*B*5 | 1 |
| Tube, Sylvania or Amperite | Type 4*E*1 (Ballast) | 1 |
| Grid caps | Medium size | 2 |
| Batteries, Burgess 20*F*2 | A battery 3-volt | 2 |
| Batteries, Burgess 4*F2H* | A battery 3-volt | 2 |
| Batteries, Burgess 5308 | B battery 45-volt | 6 |
| Battery, Burgess 5156 | C battery 22½-volt | 1 |
| Bakelite, for top and bottom of unit | 8 by 10 by 3/16 inches | 2 |
| Bakelite, mounting for cable connectors | 2¼ by 4¾ by 3/16 inches | 1 |
| Brass posts, for spacing top and bottom of unit | 5½ by ½ inches | 4 |
| Brass posts, for supporting cable connector mount | 1 by ¼ inch | 4 |
| Hydrophone | (See 6561) | 1 |
| Cable, Tyrex Simplex, type *SJ*, 1/32" insulation | 2-conductor No. 16 | 65 ft. |
| Cable, color-coded | 5-conductor | 5 ft. |
| Do | 7-conductor | 5 ft. |
| Antenna-coupling housing, brass or galv. iron cylinder, one end solid and other end with screw cap. | About 3½ inches in diameter by 5½ inches long, inside measurements. | 1 |
| Stuffing tubes, Submarine Signal Co. (for cables from drum and antenna-coupling housing). | ¾ inch | 4 |
| Copper tubing, hard drawn | ⅜ inch | 18 ft. |
| Insulators, house-bracket type, glazed porcelain | With single large wood screw mounting attached. | 6 |
| Bakelite tubing, for oscillator coil | 1⅝ by 1¼ inches | 1 |
| Bakelite tubing, for antenna-coupling coil | 21/32 by 1¼ inches | 1 |
| Wire, solid copper, enameled | No. 24 | 50 ft. |
| Miscellaneous | Screws, nuts, lumber, wire, solder, solder, lugs, and fittings. | |

## 653. Comparison of East Coast and Vincent Sono-Radio Buoys

From a structural standpoint the all-metal Vincent sono-radio buoy has numerous advantages. Because of its compactness and weight it can be easily handled on small survey vessels. It can be readily disassembled and stowed in a small space. The single-bolt clamping ring permits easy access to the interior of the drum.

The wooden East Coast sono-radio buoy is inexpensive and easy to build and, despite its comparatively large surface exposed to wind and current, it has a greater righting moment than the all-metal type of buoy. This righting moment results from a heavy counterweight and a considerable length of structure below the waterline. All this tends to make the wooden buoy long and comparatively heavy with the result that it can be handled only on the larger survey vessels. A lighter model of this buoy, however, has been built and used successfully (see **2841**).

Although the electric circuits of the two types of sono-radio buoys differ, they are about equal from the standpoint of distance performance and reliability. A sono-radio buoy is often wanted at the same station for several months in the waters off the West Coast of the United States and off Alaska, and for this reason the Vincent sono-radio buoy is designed for a long period of operation without service. A sono-radio buoy used on the East Coast or Gulf Coast of the United States is normally not needed at the same station for very long and is therefore designed for continuous service of not much longer than 1 month. The cost of the electric equipment used in the two types is about the same, but the cost of the wooden buoy structure is somewhat less than that of the all-metal type.

## 654. Adjustment of a Sono-Radio Buoy

Before a sono-radio buoy is put on station the gain of its audio amplifier must be set at the correct value to give optimum operation. The proper gain of the amplifier is determined as follows:

(1) Put the sono-radio buoy on station with its gain control set at some arbitrary value. If the value is too low, the buoy will be insensitive and returns will not be received from bombs at the expected distances; if the value is too high, excessive stray radio signals will be emitted by the sono-radio buoy. Remove the sono-radio buoy and readjust the gain to a value assumed more nearly correct and try it on station again. Continue this trial-and-error method until optimum gain value has been found. Because of the differences in characteristics of sono-radio buoys—even those of the same design—it is necessary to determine the proper audio-amplifier gain for each sono-radio buoy. With experience, it is usually possible to adjust a buoy very close to optimum value at the first or second attempt. It is usually necessary to do this only once for each sono-radio buoy.

(2) After the optimum gain setting has been found by (1), the sono-radio buoy should be brought on board ship, and a direct or comparative measurement of the audio amplifier should be made, so that the value of gain to be used for this particular sono-radio buoy is known for future use. Methods for making such measurements are described in **6541** to **6544**.

(3) Each time before the sono-radio buoy is put on station the gain should be set at optimum value by means of one of the methods described in **6541** to **6544**.

### *6541. Gain Measurements*

The method recommended for determining the audio-amplifier gain is by direct measurement. This is necessary to be able to carry out (3) of **654**. This method involves the introduction of a known voltage into the input of the amplifier, and the measurement of the resultant voltage across the output terminals of the amplifier. The voltage gain of the amplifier is the ratio of the output to input voltages. This may also be expressed in decibels, taking into account the input and output impedances.

When the sono-radio buoy amplifier is to be adjusted to a desired gain, it is only necessary to introduce a known input voltage and to adjust the gain control of the amplifier until the ratio of output to input voltage equals the desired value.

### *6542. Apparatus for Gain Measurements*

The apparatus for making direct gain measurements or adjustments consists of an audio-frequency oscillator, an attenuator, and an a-c voltmeter.

The audio-frequency vacuum-tube oscillator should be a low power type, of ¼ watt or less, with a frequency range from 50 to 1,000 cycles. It should be reasonably stable in voltage amplitude and frequency, the latter being independent of load. The output of the oscillator should be single side (one side at ground potential), and the output voltage should be controllable. The output impedance of the oscillator should be somewhere near that of the input impedance of the attenuator.

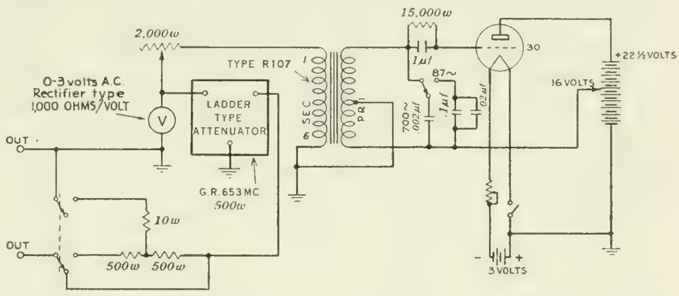


FIGURE 135.—Circuit for measuring and adjusting sono-radio buoy sensitivity.

The oscillator should be portable so that measurements can be made either in the radio room or on deck. The circuit of a simple oscillator-attenuator is given in figure 135. A number of inexpensive low power test oscillators are manufactured.

The attenuator is an electric network whose ratio of input to output voltage can be definitely controlled. This ratio is always less than unity. The input voltage is measured by means of a low-range rectifier-type a-c voltmeter, and this input voltage when reduced by the known attenuation factor of the attenuator becomes the output voltage. The attenuation factor of the attenuator can be varied by known amounts, resulting in numerous known ratios. The control dials or switches of the attenuator should be calibrated in volts of output voltage for a fixed input voltage. If some other units, such as decibels, are used, a conversion table should be employed to convert these units into volts of output voltage. The attenuator should have a frequency range from 50 to more than 1,000 cycles. The output impedance should nearly equal the input impedance of the sono-radio buoy. The minimum controllable range of the attenuator output voltage should be from 10 microvolts to 100 millivolts. A satisfactory commercial attenuator, known as the Microvolter, is type 546-*A* manufactured by the General Radio Company of Cambridge, Massachusetts.

An a-c voltmeter is used to measure the output voltage of the sono-radio buoy amplifier. This meter may be a rectifier type, such as the Weston model 301, 0–50 volt rectifier type with a resistance of 2,000 ohms per volt. The use of a vacuum-tube voltmeter is scarcely warranted since most of the measurements are of a comparative nature.

### *6543. Procedure for Gain Measurements*

The equipment described in **6542** is arranged as follows when used for testing sono-radio buoys: The output of the oscillator is connected to the input of the attenuator,

if separate units are used. Disconnect the hydrophone cable from the input of the sono-radio buoy amplifier and connect the output of the attenuator across these terminals. Remove the keying tube and connect the rectifier voltmeter across the terminals supplying voltage for this tube. The leads to the input and output should be as short as possible and in some cases should be shielded. All equipment should be grounded. A warm-up period of a half hour should be allowed before making measurements.

The following measurements should be made for each sono-radio buoy after its optimum gain has been determined in accordance with **654**(1): The oscillator frequency is adjusted to some selected value between 50 and 200 cycles or, if the amplifier is resonant at some frequency, the oscillator is adjusted to this resonant frequency. The gain control of the sono-radio buoy is set at the optimum value which has been determined. The attenuator is then adjusted to make the output voltage of the amplifier read some preselected reference value. This reference value should be used for all future measurements of all sono-radio buoys of this type. The reference voltage should be some value between 10 and 25 volts, or a value below amplifier saturation, so that a change of input voltage produces a proportional change of output voltage of the amplifier. The ratio of output to input voltage is now noted and recorded. It is this ratio that should be used for adjusting the gain of the sono-radio buoy in the future.

Practically the same procedure is followed in adjusting the gain just before the sono-radio buoy is put on station. In this case the output voltage is set at reference value and the gain control of the sono-radio buoy is adjusted until the ratio of output to input voltages equals the value previously measured and recorded.

The apparatus used for direct measurements may be a permanent part of the radio-room testing equipment or it may be portable. The advantage of using portable instruments is that in certain cases it is not necessary to remove the sono-radio buoy equipment from the drum to make the gain adjustments and measurements. The direct measurement method is the most positive method now used, although it is not completely satisfactory as it does not take into account the characteristics of the hydrophone, keying circuit, or radio transmitter. Changes in the characteristics of any of these parts may affect the performance of the sono-radio buoy, and unless the amount of change is known, it cannot be compensated for by the direct measurement method. Another undersirable feature of this method is that the measurements require considerable time and care.

A variation of the direct measurement method, which has the advantage of being simpler and quicker to perform, may be used to adjust a sono-radio buoy, although the results are not quite so positive. The apparatus for gain measurements should consist of an oscillator and attenuator similar to those described in **6542**, except that they should be portable. It is not necessary to remove the electric equipment from the buoy—merely disconnect the hydrophone and connect the attenuator in its place. From previous tests as described in **654**(1) the value of the input voltage to the audio amplifier at optimum gain, for satisfactory operation, is known. Adjust the test-circuit attenuator until this value of voltage is across the input of the amplifier. Starting with the gain control of the amplifier at a low value, increase the gain slowly until the radio transmitter just starts to operate. Repeat this operation several times until the position of the gain control has been accurately determined for the point of transmitter operation.

The point of operation of the transmitter can be established by means of some indicating device coupled to the antenna circuit. Some of these devices are described

in **6545**. The keying threshold may also be indicated by the aid of a radio receiver. After replacing the hydrophone, the sono-radio buoy is ready to be put on station.

### *6544. Other Methods of Gain Adjustment*

A method used to a limited extent for gain adjustment is called the loud-speaker method. The hydrophone is placed at a fixed distance in front of a loud speaker from which a tone of fixed amplitude and frequency can be emitted. The gain of the sono-radio buoy is then adjusted to give some amplifier output voltage, or to a value which will just cause the radio transmitter of the unit to operate. The intensity of the sound from the loud speaker and its distance from the hydrophone are fixed by the value of gain needed by the sono-radio buoy for optimum operation as determined by **654**(1). This method has the advantage of including all the equipment that is subject to change, but the measurements cannot always be accurately repeated and the method cannot be considered as accurate as that described in **6543**.

To make these adjustments, a loud speaker or headphones are needed near enough to the buoy so that a radio signal can be heard and, since the adjustments are often made at some distance from the radio room, an extension must be provided from the radio receiver—or a portable radio receiver may be used.

A most inaccurate method, which unfortunately is frequently used, is to use a sound made orally or by clapping one's hands in front of the hydrophone. The gain is then adjusted until the radio transmitter just starts to operate. The loudness of noise and the distance from the hydrophone for optimum gain adjustment are determined by test. A variation of this method is used with the sono-radio buoy suspended at the ship's rail with the hydrophone in the water. The ship's machinery then becomes the source of sound. The gain of the sono-radio buoy is then adjusted as above until this noise causes the radio transmitter to operate. The success of this method depends on the judgment and experience of the technician. Its only advantages are that little time is consumed, no extra apparatus is needed, and the test involves all parts of the buoy.

### *6545. Adjustment of the Radio Transmitter*

Just before a sono-radio buoy is put on station its radio-frequency circuits must be tuned. Most of the sono-radio buoys used by the Coast and Geodetic Survey are arranged so that the radio transmitter can be tuned by adjusting the circuits in the antenna coupler. (The other radio-frequency circuits need be tuned only occasionally, as they should remain in adjustment for long periods of time.) Ideally, the final tuning should be done after the sono-radio buoy has been put in the water, as then the antenna characteristics are not influenced by the metal of the ship. However, this can be done only from a small boat and it is time-consuming; moreover, it is difficult to make such adjustments from a boat, unless the sea is extremely smooth. For practical reasons then the final tuning must be done while the sono-radio buoy is still on board ship.

The antenna should be vertical during the tuning, so as to be less affected by the metal of the vessel. A convenient method is to tune the sono-radio buoy while it is held over the side of the vessel, with its antenna in a vertical position, ready to be anchored. Another satisfactory method is to use a dummy antenna circuit which is equivalent to the antenna when the buoy is in the water. The advantages of this latter method are that the metal of the ship has no effect on the dummy antenna circuit and the adjustment will be nearer what is required when the sono-radio buoy is in the

water. The dummy antenna circuit is shown in figure 136. When this is used for tuning a sono-radio buoy, the antenna is disconnected and the dummy antenna connected in its place.

Numerous methods may be used to indicate when the antenna and radio-frequency circuits are properly tuned. The antenna lead can be opened near the antenna coupler and a thermocoupled type of radio-frequency ammeter inserted. It should have a range of 0 to 250 milliamperes or more, depending on the power used. A second and better method is to couple a low energy-absorbing circuit loosely to the antenna and to tune the radio-frequency circuits by noting the reading on an indicating meter. The energy-absorbing circuit may consist of a coil of two turns of wire about 3 inches in diameter, connected to a rectifier-type voltmeter. A second circuit that is very satisfactory consists of a short antenna connected to a vacuum-tube voltmeter, the antenna being loosely coupled to the antenna of the sono-radio buoy.

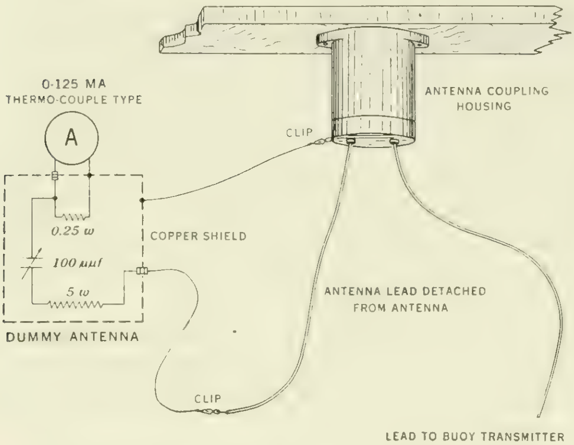


FIGURE 136.—Sono-radio buoy dummy tuning antenna.

When tuning the antenna, the radio transmitter is usually operated at reduced power by closing a key for this specific purpose. The condenser of the antenna-coupling circuit is tuned by removing the threaded plug in the antenna-coupling housing and inserting a screwdriver in the slotted end of the condenser shaft. The best results are obtained when this condenser is adjusted so that the reading on the tuning indicator device is a little below peak value when the condenser is on the minimum capacity side of peak tuning.

## 655. OPERATING DIFFICULTIES

Abnormal performance of a sono-radio buoy is usually disclosed in one of two ways—either it is too insensitive to distant bombs, or there is an excess of stray signals.

A subnormal range of a sono-radio buoy may be caused by:

(*a*) The sono-radio buoy is located at a place where the bomb sounds are not reaching the hydrophone.

(*b*) Insufficient audio-amplifier gain. The gain may have been improperly adjusted originally or may have changed because of deteriorated parts.

(*c*) Faulty hydrophone. Either the electroacoustic unit is defective or water is leaking into the hydrophone housing or electric cable.

(*d*) Weak radio signals may result from defective transmitting equipment, improper tuning, damaged antenna, or water leaking into the drum or antenna-coupling housing. They may also result from poor radio transmission conditions.

An excess of strays may result from the following:

(*e*) The audio-amplifier gain may be excessive, owing to improper gain adjustment, regeneration of the amplifier caused by improper design or construction, or decrease of C battery bias voltage.

(*f*) Defective parts may cause electric noises in the amplifier.

(*g*) Salt water leaking into the drum will sometimes cause the electric equipment to operate, producing excessive strays, as a preliminary to final cessation of operation.

(*h*) The hydrophone may be fouled with other parts of the buoy, such as the anchor or relieving buoy cable. Noises may be caused by shackles, counterweight fastenings, or other gear.

(*i*) Vessels passing near the sono-radio buoy. Noise from such a source may last from a few minutes to as long as an hour.

### 656. HYDROPHONES

A hydrophone is a subaqueous sound-detecting device used in Radio Acoustic Ranging to receive the sound energy of a distant underwater bomb explosion and to convert the sound energy to electric energy. Most hydrophones consist of a watertight housing containing an electromagnetic, piezoelectric, or other electroacoustic device, which is coupled to the housing in such a way that the sound impinging on the housing, or its diaphragm, is transmitted mechanically to the electroacoustic device which converts this mechanical energy to electric energy. For Radio Acoustic Ranging the hydrophone is submerged in water at a suitable depth and connected to an audio amplifier by means of a waterproof electric cable.

As sound passes through an elastic medium there is an alternate condensation and rarefaction of the medium at a given point, resulting in a corresponding increase and decrease of the pressure at this point. In addition, at any point, the particles of the medium undergo regional displacement forward and backward along the direction of sound propagation, but without any progress from this cause. (See **621.**)

Sound-detecting devices, such as hydrophones, are operated by this pressure variation and particle displacement. Sound detectors designed to use the differential pressure of the medium caused by the sound wave are known as pressure-operated instruments, and those designed to be operated by particle displacement are known as displacement or velocity types. No instrument is exclusively operated by either pressure or displacement—each instrument is typed according to its predominant mode of operation, i. e., either pressure or displacement. Hydrophones, like all other sound detectors, can be classified either as pressure or displacement instruments. Most hydrophones are pressure types, for this type is more sensitive because of the high radiation resistance of water, but displacement types are also used where the lack of sensitivity is compensated for by other advantages.

Hydrophones used on sono-radio buoys must be designed to have certain characteristics favorable for use in Radio Acoustic Ranging, which are:

(*a*) The hydrophone must be reasonably sensitive. Extreme sensitivity is not necessary, however, for the audio-amplifier gain can be increased to compensate for some lack of hydrophone sensitivity. The hydrophone and audio amplifier must be designed so that together they will furnish the required sensitivity.

(*b*) The hydrophone must respond favorably to the frequencies of the sound from a subaqueous explosion. There are little quantitative data on the frequency spectrum that includes the maximum amount of sound energy from subaqueous explosions, or the variation in the frequency spectrum caused by various conditions of the medium, depth, distance, bottom, and other factors such as the sizes and kinds of bombs used. However, there is sufficient evidence to show that, under average conditions of R.A.R., the frequency of most of the sound energy is below 300 cycles. The hydrophone should be designed, therefore, to favor frequencies below 300 cycles. The frequency characteristics of the hydrophone need not be flat—in fact there may be some advantage in having resonant characteristics.

(*c*) The hydrophone must not be directive to a marked extent. An advantage might be gained by the use of a directive hydrophone with a sensitivity null in a vertical direction to exclude noises originating on or near the water surface, but most hydrophones used by the Coast and Geodetic Survey in R.A.R. are not intentionally made directive.

(*d*) The sensitivity of hydrophones of the same design must be uniform throughout the useful frequency spectrum. This is especially important in hydrophones used on sono-radio buoys, as nonuniform hydrophone characteristics would require a redetermination and readjustment of the audio-amplifier gain each time the hydrophone of a sono-radio buoy was changed. Where all hydrophones of a type have uniform characteristics the sono-radio buoys and hydrophones are interchangeable.

(*e*) The hydrophone should be designed to minimize noises created by water currents or caused by the motion of the hydrophone through the water.

(*f*) The hydrophone must be portable for easy handling and light so that elaborate and bulky supports are not necessary.

(*g*) The hydrophone must be strong and watertight, to withstand the hydrostatic pressure at the depth where the hydrophone is normally suspended and all the shocks to which it may be subjected during the handling of the sono-radio buoy.

During the development of R.A.R. many experimental types of hydrophones were tested and a number of different designs have been used. Most of these were intended for use with shore stations and need not be described, since sono-radio buoys are now used almost exclusively.

Two principal types of hydrophones are now used by the Coast and Geodetic Survey: (1) The Dorsey hydrophone—used almost everywhere on the Atlantic and Gulf Coasts and, since 1940, more and more in Alaska waters; and (2) the Vincent hydrophones—in the past used mostly on the Pacific Coast and in Alaska waters.

### *6561. Dorsey Hydrophone*

The Dorsey hydrophone is a pressure-operated device with a thin hard-rolled brass diaphragm attached to a massive body which is little influenced by the sound wave. As the diameter of the diaphragm is small compared to the wave length of the bomb sound, this unit has little or no directivity.

The assembled hydrophone is illustrated in figure 137. A flange near the edge of the diaphragm fits loosely into a circular groove cut in the heavy brass base, a circular gasket of square cross-section

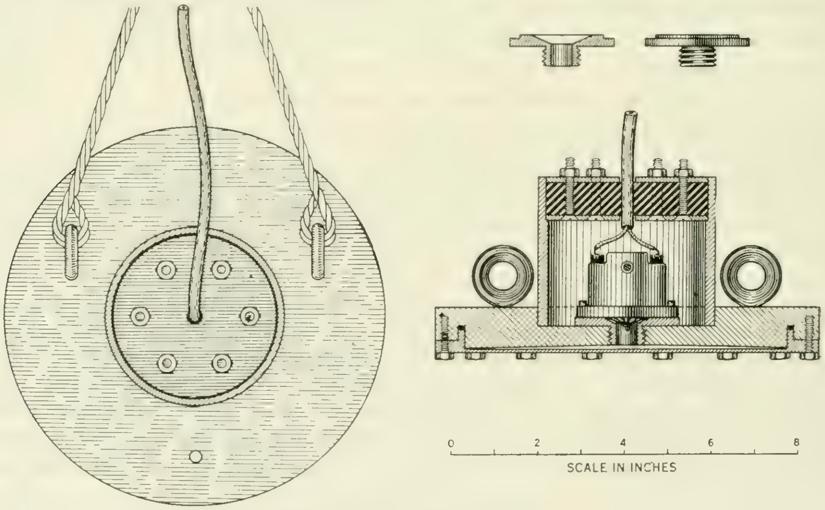


FIGURE 137.—Dorsey hydrophone.

fitting in the groove. The diaphragm and base are bolted together with 16 ¼–28 brass bolts. A cylindrical section of brass tube is secured by watertight soldering in a recessed part of the back of the base plate. The back end of the cylindrical section is closed by a rubber plug. The plug is a disk

of live rubber clamped between two circular brass plates by means of six ¼–20 brass bolts that pass through the rubber. A central hole passes through the brass and rubber for the passage of an electric cable. When the plug is inserted in the end of the cylindrical section and the six brass nuts are tightened, the rubber is compressed by the plates and expands normal to the direction of compression to seal the opening.

By means of an adapter an electromagnetic unit is screwed into the loose threads of a hole that connects the cavity behind the diaphragm with the cavity of the cylindrical section, the electromagnetic unit being in the cylindrical section. The outside diaphragm and the diaphragm of the electromagnetic unit are coupled by means of the air in the cavity between the diaphragms. The electromagnetic unit used in the Dorsey hydrophone is No. *H*-56741-1, made by the Automatic Electric Company of Chicago, Illinois. It consists of a balanced armature suspended between the pole pieces of a permanent electromagnet, the armature being connected to a small aluminum-alloy diaphragm by means of a pin. The impedance of this unit is 900 ohms. The calculated natural frequency of the hydrophone diaphragm in water is 141 cycles. There are additional resonant points because of the air cavity and the resonance of the electroacoustic unit.

The Dorsey hydrophone was formerly used with ship stations and is now used almost exclusively with sono-radio buoys on the Atlantic and Gulf Coasts of the United States.

### *6562. Suspension of the Dorsey Hydrophone*

Where the sono-radio buoy is connected to a relieving buoy that is anchored, the hydrophone should be suspended by a cable from the sono-radio buoy. It should be suspended about 7 fathoms below the water surface. This depth is not at all critical, but it is essential that once a depth is selected it should be used for all sono-radio buoys of one control scheme. Where there are strong water currents the diaphragm of the hydrophone should be horizontal. It is suspended thus by a yoke attached to the three eyebolts on the back of the base plate of the hydrophone. The upper end of the yoke is attached to the suspension cable which in turn is attached to the sono-radio buoy. Where the water currents are weak there is some advantage in keeping the diaphragm of the hydrophone vertical. It is suspended thus by a yoke attached to only two of the three eyebolts on the back plate of the hydrophone.

The suspension cable should be suitable ⅜-inch flexible cable. The electric cable from the buoy to the hydrophone should be Tyrex Simplex, type *SJ*, No. 16, two-conductor, with ³⁄₃₂-inch insulation, or equal. The electric cable is lashed to the suspension cable at 2-foot intervals, leaving slack in the electric cable between lashings to avoid any strain on it. Other details of this hydrophone suspension are described in **2841**(A).

Where the sono-radio buoy is anchored without an intermediate relieving buoy, the hydrophone should be suspended from the anchor cable in such a way as to avoid fouling. The hydrophone may be suspended in the center of a triangular frame of angle iron by means of six rubber straps, two straps to each side of the triangle. The frame may be made of angle iron 1½ inches wide by ¼ inch thick, the length of each side being 35 inches. For suspension, one side of the triangle is clamped to the anchor cable at a distance of about 45 feet from where the cable joins the buoy. The electric cable is fastened to the anchor cable at 2-foot intervals. The electric cable should be parceled to protect it from chafing against the anchor cable or any part of the buoy.

### *6563. Vincent Hydrophones*

There are several models of Vincent hydrophones, whose principles of operation are very similar, although they differ in size, material, and construction.

The housing of one of the first Vincent hydrophones was of cast aluminum and it had the following dimensions:

| | Inches | | Inches |
|---|---|---|---|
| Diameter | 8¼ | Thickness of end | ¼ |
| Length | 5 | Diameter of opening | 4 |
| Thickness of cylinder wall | 3/16 | Length of collar | 1¼ |
| Thickness of diaphragm | ¼ | | |

The air pressure inside the housing is increased to counteract partly the hydrostatic pressure. An electromagnetic unit is mounted by a single screw on the center of the bottom of the housing. The motion of the housing is transmitted to the armature of the electromagnetic unit by a system of levers, relative motion between the armature and the pole pieces occurring because of the inertia of the electromagnetic unit. The electroacoustic unit that has been most frequently used in this hydrophone is made by Nathaniel Baldwin of Salt Lake City, Utah. But various other kinds of electroacoustic units and a specially adapted piezoelectric unit have also been used.

Comparative tests show that the Vincent hydrophone is somewhat less sensitive than the Dorsey hydrophone, but this can be easily compensated for by the use of additional audio amplification (see **656** (*a*)). One of the advantages of the Vincent hydrophone is that it is inexpensive and easy to construct. It was first used at R.A.R. shore stations, but was readily adapted for use with sono-radio buoys.

A smaller Vincent hydrophone was designed especially for use with sono-radio buoys. The housing is a small cylinder bored from a solid rod of Duralumin. One end of the cylinder is solid, the other being fitted with a watertight rubber plug. The electroacoustic unit is mounted on the inside bottom of the housing. This hydrophone has been submerged to 150 fathoms without injury. This hydrophone and the rubber sheath and cast-iron shell in which it is usually enclosed for use in R.A.R. (see **6564**) are illustrated in figure 138. The housing of the unit has the following dimensions:

| | Inches | | Inches |
|---|---|---|---|
| Diameter | 1⅞ | Thickness of cylinder wall | ⅛ |
| Length | 3½ | Thickness of cap and end | ¼ |

The electroacoustic unit used is an electromagnetic type, made by the Automatic Electric Company. It has an impedance of 900 ohms.

### *6564. Suspension of Vincent Hydrophones*

The large Vincent hydrophone may be suspended from a sono-radio buoy in one of two ways. One method is to hang the unit directly below the buoy at the desired depth by means of a cable. A clamp is placed around the housing to which the supporting cable is connected, and to the bottom of which a weight is attached sufficient to keep the hydrophone submerged. The electric cable is lashed to the supporting cable at regular intervals. Parceling must be used wherever there is a possibility of chafing between the electric cable and other gear.

Another method of suspension is to anchor the hydrophone separately. The buoyant hydrophone is attached to its own 50-pound anchor above which it floats submerged 4 or 5 fathoms above the bottom. The anchors of the hydrophone and the sono-radio buoy are connected by a cable, and the hydrophone is electrically connected to the sono-radio buoy by a rubber-covered electric cable lashed to both anchors and along the sono-radio buoy anchor cable. The electric cable is run through rubber hose to protect it from chafing against the bottom or the anchors. The distance between the anchors should be about 150 feet.

The entire assembly must be prepared in advance—the hydrophone anchor with hydrophone attached is lowered first, the cable connecting it with the buoy anchor is stretched taut, and then the buoy anchor is lowered from the vessel.

Of the two methods of hydrophone suspension, the first simplifies the operation of anchoring and removing the sono-radio buoy. The second method eliminates water noises to a large extent, and the distances at which the installation can be used in R.A.R. are comparable with those from shore stations. The second method should be used for sono-radio buoys that are to be left at the same station for several months and where hydrography is to be controlled at long distances from the sono-radio buoy.

The electric cable used with the Vincent hydrophones is a single-conductor tinned aircraft wire, 3/16 inch in diameter, preformed 49-strand (7 by 7), insulated with a 60 percent rubber compound, the outer diameter being ½ inch.

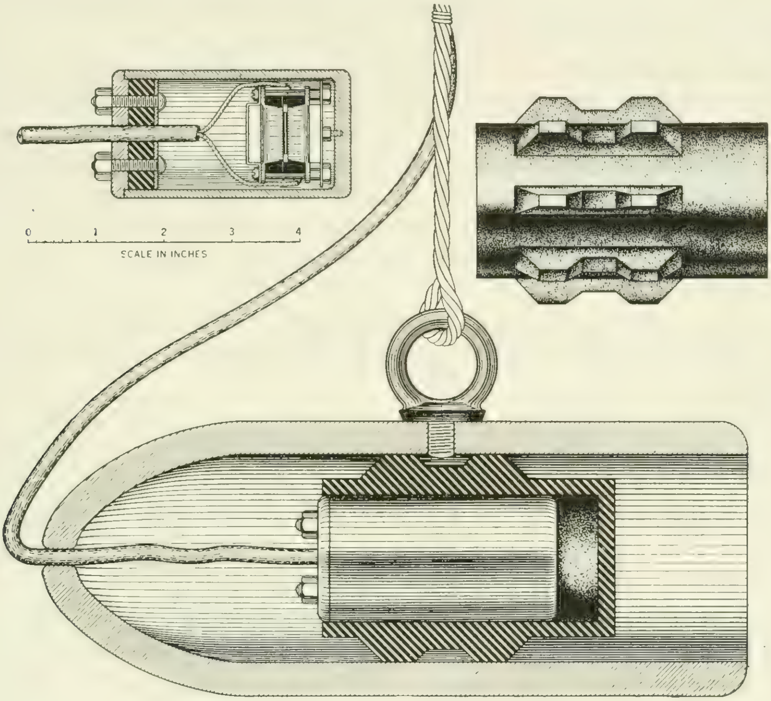


FIGURE 138.—Vincent sono-radio buoy hydrophone.

The small duralumin Vincent hydrophone is suspended directly below the buoy. The housing of this unit is enclosed in a rubber sheath (**K**-tube unit rubber housing, see **5213**) and the whole is put into a cast-iron shell approximately 12 inches in length and 4½ inches in diameter. The shell is a hollow cylinder rounded at one end and open at the other. The hydrophone unit and rubber sheath are placed in the shell so that the flat end of the hydrophone is nearest the opening, the electric cable entering through a hole in the rounded end of the shell. The suspension cable is secured to an eyebolt attached to the shell. (See fig. 138.) The shell is intended to hang horizontally and to afford some streamlining. It has been used successfully in strong currents.

### *6565. Tests and Maintenance of Hydrophones*

Although quantitative measurements of hydrophone characteristics would be valuable, they are not attempted because they would require equipment whose use is not practicable on board most survey ships. However, certain tests should be made,

before a sono-radio buoy is put in the water, to determine if the hydrophone is operating normally.

Before the hydrophone is attached to the sono-radio buoy, a continuity test should be made of the windings of the electroacoustic unit, and leakage measurements should be made between each wire of the electric cable and the hydrophone case, neither wire being grounded. Next, connect a low-voltage high-impedance rectifier-type voltmeter across the hydrophone wires and tap the hydrophone gently, noting the voltmeter peak reading. The normal peak voltage should be determined by experiment for each type of hydrophone. The choice of meter depends on the impedance of the electroacoustic unit. Even units of low impedance will show a reading on a sufficiently sensitive commercial type of high-impedance voltmeter.

The most frequent cause of hydrophone failure is leakage, usually due to improper assembly of the hydrophone. If the outside diaphragm of the Dorsey hydrophone is removed, a new rubbber gasket should be used and fitted carefully into the annular channel when the diaphragm is replaced. The 16 stud bolts are then tightened evenly until the outer edges of the diaphragm and the base plate meet. When the rubber plug is replaced in a hydrophone that uses such a plug, the compression bolts should be tightened, but they should be given a final tightening just before the sono-radio buoy is put in the water.

If water leaks into a hydrophone, disassemble it completely and wash all parts thoroughly in a solution of hot water and soda, after which they must be rinsed in fresh water and dried.

A sharp mechanical blow, or the explosion of a bomb too close to the hydrophone, may force the armature of the electromagnetic unit against one of the pole pieces. To rectify this, the unit must be removed and the armature rebalanced either by carefully bending it back into place or by means of an adjustment screw if one is provided.

## 66. R.A.R. BOMBS AND EXPLOSIVES

In Radio Acoustic Ranging (R.A.R.) a sound must be created that will travel in the water in all directions so that it may reach a receiving unit located in any direction from the source. An explosive type of bomb has been used for this purpose from the beginning, and it still seems best adapted. A sound of great intensity is required, and no electric or mechanical means has yet been found to produce a subaqueous sound of intensity sufficient for the distances required.

Although explosives are a hazard on board ship, their use is necessary in R.A.R. pending the development of another method of producing the required subaqueous sound. But if explosives are properly stowed and thoroughly understood by the personnel detailed to handle them, the hazard may be minimized and the explosives may be carried and handled on board with little risk of accident. Only the explosives and accessories generally used in R.A.R. are described, together with the required methods of stowage and the necessary precautions to be exercised in the handling of explosives on board ship.

### 661. Types of Bombs

Any type of explosive suitable for use under water may be used for R.A.R. bombs. Dynamite has been used with satisfactory results, but it is unstable and more dangerous than TNT and should be used only as a substitute when TNT is not obtainable.

Trinitrotoluene (TNT) is in general use for R.A.R. bombs. It is stable, offers no difficult stowage problems, and is well adapted for the construction of bombs on board

ship. The types of bombs differ only in the type of containers and in the method of detonation.

In the early development of R.A.R., bombs were exploded electrically by closing two switches, an ordinary electric switch located in the radio room and a safety switch near the bombing station (see **6841**). The bombs were towed about 200 feet astern of the ship by a rope to which was attached a twin-conductor cable which carried the current to explode the electric detonator. The bomb was suspended from a 5-gallon can buoy and weighted with a 15-pound lead sinker. Although electric detonation is a positive means of exploding bombs at any desired depth, it is no longer used in R.A.R., except for experimental purposes when the exact time of the explosion must be recorded (see **664**). Electric bombs require excessive time to prepare, the survey vessel must stop or slow down while they are fired, and it is difficult to keep track of whether the two electric switches are open or closed.

The types of bombs in general use are exploded by a fuse and a fuse detonator that is inserted into the TNT through a suitable hole in the container. This type of bomb is simple to construct and requires no preliminary preparations, and as soon as the fuse is ignited the bomb is thrown overboard.

## 662. Bomb Containers

For best results a bomb container should be made of a rigid material so that the detonation of the explosive will be complete before the container bursts. If the explosive gases are thus restrained until the detonation is complete, the resulting explosion produces a highly compressed sound wave that has a greater range than one from an explosion in a container that is easily shattered. Ordinary glass bottles, tin cans, and special cast-iron spheres are used for bomb containers.

Commercial glass bottles are satisfactory, except that in the required sizes they are generally not well shaped for the purpose, and it is often difficult to insert the detonator securely. The cast-iron spheres are used on special occasions, but they are heavy and expensive, for they must be specially cast in rather small quantities at foundries which are often inconveniently located. Tin cans of various sizes are in general use because they are inexpensive and they may be readily obtained. A better container is desirable, however, and it is possible that a heavy glass sphere may be specially designed for use as a bomb container.

The iron spheres are usually cast with walls ½ inch thick, with an outside diameter of 7½ inches, and with one flat surface about 2½ inches in diameter on which they will sit upright. They are provided with a hole suitably arranged so that a stopper with a fuse hole may be inserted therein. A bomb of this design and size will contain about 4 pounds of explosive. A smaller cast-iron bomb of identical design is sometimes used. It is only 4¾ inches in diameter and contains about 1 pound of explosive.

The cans used for bomb containers are the ordinary commercial type with a friction top; they need not be tinned if an untinned metal can is available and less expensive. Various sizes are used depending on the characteristics of the area and the distance from the receiving units. Three sizes are commonly used, of ¼-, ½-, and 1-pint capacities, which will contain about ¼-, ½-, and 1-pound of explosive, respectively. A ⅛-pint size is occasionally used for very short distances but it is only a little more effective than a detonator used alone. A quart size is also occasionally used for very long distances but it is generally little more effective than the pint size.

For the best transmission of sound, the bombs should not explode too close to the surface of the water. An additional weight must be placed in tin can bombs to make them sink deeper before they explode. Pieces of scrap metal have been used for this purpose and dry sand and concrete have also been used. The quantity of sand required to make the bombs sink to a sufficient depth reduces the explosive capacity, but this results in very little apparent difference in the effective range. Melted pig lead is usually used to weight the tin containers, however, the quantity required varying with the size of the container. About 13.5 ounces of lead is required to weight a 1-pint bomb, and a proportional weight for other sizes. This proportion of lead is sufficient to make the various sizes of bombs sink at a rate of about ½ fathom per second. (See **6846**.)

A hole, slightly larger in diameter than the detonator, is punched with a round metal tool in each tin can top. This hole is punched from the inside of the top so that the burs left around the hole will be on top when the lid is in place. The detonator, with fuse attached, is inserted into the TNT through this hole. The fuse protrudes through the hole, the burs being pressed around it to hold it in place and to seal the can somewhat.

### 663. Construction of Bombs

Bombs are generally constructed in two or three separate operations; they are prepared for use in a preliminary operation but are finally completed only just before being ignited and thrown overboard (see **6842**). If the bombs are weighted with sand or scrap metal there is only one preliminary operation, for the container may be filled with TNT immediately after the weights are placed in the cans—but if they are weighted with melted pig lead, the lead must be allowed to cool before the TNT is added.

Where melted pig lead is used for weighting, the tin cans should be prepared while in port to avoid the possible fire hazard on board ship, and in such case as many cans of various sizes should be weighted as will probably be needed during the next month, assuming there is sufficient stowage space. However, if there is a suitable fireproof area in the fiddley, or elsewhere, the cans may be weighted on board. The pig lead, after being cut into pieces that will go in the melting pot, is melted over a suitable forge or large gasoline blowtorch. The cans are set in a shallow tray containing about one-half inch of water and the melted lead is poured into each as required to furnish the necessary weight. An experienced man will be able to estimate the required amount within satisfactory limits.

After the cans have cooled to atmospheric temperature they may be filled with TNT. Only a sufficient number to fill the bomb locker (see **6841**) should be prepared at one time. Most port regulations forbid the handling of any type of high explosive in the harbor, so the containers must be filled while at sea. This should be done during good weather in a protected spark-free space on deck, on the lee side if possible, and the space should be surrounded on three sides with a canvas windbreak to prevent the scattering of loose grains of TNT. The deck should be covered with heavy canvas so that it will not be impregnated with TNT (see **666**).

The cans are usually filled from an open box of TNT by a man wearing a special pair of long heavy rubber gloves to protect his hands and arms. A dust mask is also advisable, for TNT is injurious to the respiratory system if inhaled. (See **666**.) Each can is filled gradually, the TNT being compacted firmly into the can in the process. To be certain of detonation the TNT must be firmly packed in the container. A wooden implement, similar to a potato masher, with a flat bottom and a diameter

slightly smaller than the opening in the can, should be used, although hand packing is satisfactory. After the cans have been filled, the punched tops (see **662**) are pressed on, the excess TNT is removed, and the preliminary preparation of the bombs has been completed.

TNT should be poured through a funnel into any container with a small hole. A small stick may be used to pack the loose TNT and, after packing, the container is again filled and repacked, and the procedure is repeated until the container is fully packed.

A number of containers may be filled with TNT before the bombs are needed, but **detonators and fuses must never, under any circumstances, be inserted at this time.** The filled bombs are stored in a carefully selected safe place, but the **detonators are not inserted until just before a bomb is to be used** (see **6842.**)

The approximate cost of the materials in the different size tin can bombs in 1940 was as follows:

| Size | Container | TNT | Fuse | Lead | Detonator | Total cost |
|---|---|---|---|---|---|---|
| ⅛ pint | 1.3¢ | 2.5¢ | 0.5¢ | 0.6¢ | 1.7¢ | 6.6¢ |
| ¼ pint | 1.5 | 5.0 | 0.5 | 1.2 | 1.7 | 9.9 |
| ½ pint | 2.3 | 10.0 | 0.5 | 2.4 | 1.7 | 16.9 |
| 1 pint | 2.5 | 20.0 | 0.6 | 4.8 | 2.2 | 30.1 |
| 1 quart | 3.5 | 40.0 | 0.6 | 9.5 | 4.4 | 58.0 |

The above costs are based on the following prices: Pig lead at 5.6¢ per pound; TNT at 20¢ per pound; No. 6 detonators at \$17.00 a thousand; No. 8 detonators at \$22.00 a thousand; fuse at \$6.30 a thousand feet.

### 664. Deep-Sea Bomb

In R.A.R., bombs are usually made to explode approximately at the depth of the hydrophone (see **6843**), but under certain conditions and in experimental investigations it is sometimes desired to explode bombs at great depths. The best way of doing this is with an electric detonator, for TNT bombs cannot be detonated by fuse in depths of water much greater than 25 fathoms. Below this depth the increased pressure prevents the powder train in the fuse from burning and misfires result. It is possible to protect the fuse in a capped pipe screwed into a metal bomb container, but the construction is expensive and time-consuming.

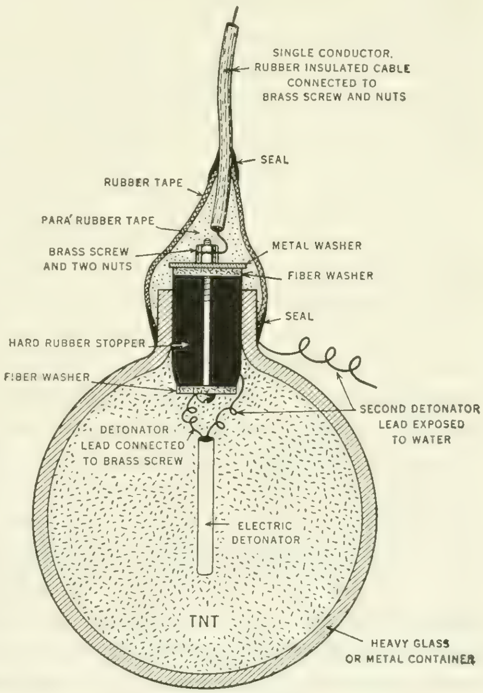


FIGURE 139.—Bomb for deep detonation.

The type of bomb illustrated in figure 139 has been successfully detonated at a depth of 700 fathoms. Any type of heavy glass bottle or thick metal container, with an opening into which a rubber stopper may be inserted, may be used in its construction. One of the electric leads of the detonator is attached to the head of a brass screw (No. 8–32) which passes through the stopper. The other lead passes between the stopper, which is slightly grooved, and the container, to make contact with

the surrounding water; a piece of metal may be attached to this wire to increase the surface area. The brass screw has two nuts, the lower of which is tightened to expand the stopper and to hold it firmly in the container. A single-conductor cable is connected to the brass screw by the upper nut, and the screw thus forms part of the conductor to the detonator. This connection at the top of the screw must be well insulated from the water. The exposed areas should be completely covered with Pará-rubber tape, which is then covered with ordinary rubber tape. As an added precaution, the junctions of the tape with the conductor cable and the container may be sealed with collodion or any other sealing compound, although this is probably unnecessary.

This type of bomb may be weighted, if necessary, by attaching a piece of Manila line to the conductor cable about 4 feet above the bomb, the line being long enough to allow the weight to hang below the bomb. The strength of the conductor cable must be considered, for too heavy a weight might part the wire in some types of cable.

## 665. Storage of Bombs

Bomb containers filled with TNT should be stowed in a safe place on board and receive the same care as the supply of explosives (see **666**). The bomb locker should be large enough to stow the number of bombs required for about one week's operations. If its size is inadequate, the prepared bombs should be stowed in a locked magazine, if one is available, or in a locker provided on the upper deck near the stern.

**No explosives shall be permitted on board while the ship is undergoing repairs.** During any extensive lay-up period, the supply of TNT, detonators, and all prepared bombs should be boxed and arrangements should be made to stow them at the nearest United States Army or Navy ammunition dump. Arrangements can generally be made for an ammunition barge and tug to transport these supplies to the dump. If the amount of explosives and the number of detonators remaining at the end of a season's work is small, they should be thrown overboard at sea in deep water.

## 666. Trinitrotoluene (TNT)

Trinitrotoluene, commonly called TNT, is used in making the bombs used for R.A.R. It is one of the safest high explosives. It is relatively safe to handle and stow on board ship, it does not readily absorb and retain moisture, it lacks any tendency to form unstable compounds with metal, it is practically insoluble in water; and it possesses powerful explosive properties, so that a small quantity of it will produce the sound wave of high intensity required for R.A.R. Properly purified TNT, when correctly stowed, remains stable for long periods of time; but it will react with alkalis, such as sodium hydroxide or sodium carbonate, to form unstable sodium salts which are quite sensitive.

TNT is manufactured by various processes, all of which involve the nitration, by a mixture of nitric and sulphuric acids, of toluene, a hydrocarbon derived from various tars. It is a crystalline powder, resembling powdered brown sugar in appearance, although in different grades of refinement its color and appearance vary. The most refined grade, grade A, is pale yellow in color, but grade B, a less refined product, contains more impurities and is darker, sometimes reddish brown in color. Both grades may be obtained from the United States Navy; grade A should be used. Although not quite as satisfactory, grade B may be substituted when grade A is not obtainable.

TNT has a high chemical stability, even when subjected to a temperature as high as 65° C. for a considerable period. At 180° C. there is a slow evolution of gas and at 300° C. it ignites. When a small unconfined quantity is ignited, it burns slowly, giving forth a dense black smoke. It is quite insensitive to friction or ordinary shock, but it can be detonated by severe impact between metal surfaces or by a rifle bullet.

TNT, in crystalline form, is readily exploded with a No. 6 detonator. When compressed to a high density (packed by hand, its density may range from 0.75 to 1.0) a No. 8 detonator is required, and when cast in blocks a booster charge of crystalline TNT or other sensitive explosive is necessary to obtain detonation. In R.A.R., a No. 6 detonator will serve satisfactorily to explode ¼- and ½- pint bombs, but a No. 8 detonator is required to explode consistently 1-pint and 1-quart bombs. The latter sometimes fail to explode even when a No. 8 detonator is used, because the tops of the cans may be blown off before the TNT is detonated. It is sometimes possible to facilitate detonation either by securing the tops more firmly or by placing one or two extra detonators in the TNT adjacent to the detonator in which the fuse is inserted.

All TNT is poisonous under certain conditions and proper precautions must be taken by those handling it to avoid inhaling the dust and to avoid unnecessary contact with it. The place where it is to be handled must be well ventilated, and the use of a dust mask is advised. Rubber gloves should be worn, or the hands may be protected by washing them in advance in a lotion which is made as follows:

To ¼ ounce of borax, placed in a boiler, add 280 cubic centimeters of distilled water. Heat to a boiling point, then add 2.2 ounces of casein. After the casein is dissolved, add an additional 250 cubic centimeters of distilled water and let cool. When this solution is placed on the hands and allowed to dry, it closes and protects the pores.

Clothing that has become impregnated with TNT must not be worn thereafter. Boxes in which TNT is supplied, especially grade B, become impregnated in time. This does not reduce the effectiveness of the explosive, but the boxes become highly inflammable and, if sufficiently impregnated, they may be exploded in a manner similar to low-grade dynamite. Therefore, **TNT must not be left in contact with wooden parts of the ship** for any period of time, and the wooden boxes in which it is packed must be disposed of promptly after they are emptied.

TNT should be handled as little as possible and kept free from dust, oil, acid, and alkali. It should be kept dry and not exposed to direct sunlight or subjected to high temperature. In case of a serious fire near TNT, a violent explosion is likely.

If the vessel has an ammunition magazine, the supply of TNT must be stowed in it at all times. The flooding system of the magazine should always be in proper working order and the temperature in the magazine should be taken frequently enough to detect any important change. Nothing except explosives and bombs shall be kept in the magazine. Prepared bombs should be stored in boxes or secured in racks. The magazine shall be opened only with the permission of the executive officer, who shall have charge of the key. Whenever the magazine is open it shall be under the constant supervision of the chief bomber (see **6714**).

If the vessel is not provided with a magazine, the TNT supply should be stowed in a locker, lined with an inert metal such as copper, zinc, or lead, from which sparks cannot be struck. This locker should be constructed and secured on the afterdeck of the ship in a manner so that it can be thrown overboard quickly and easily in case of a serious fire on board.

Handling of explosives shall be kept at a minimum. The handling of large quantities of explosives and their stowage in the magazine shall be carefully supervised by an officer who shall permit no relaxation of any safety measures.

### 667. DETONATORS

High explosives are fired by means of intermediate agents known as detonators. These are small copper tubes, partly filled with a small charge of a powerful explosive which serves as a primer to detonate the principal explosive by a combination of shock and intense heat. There are two general types of detonators; one that is set off by an electric current, and another that is made for use with a fuse. The fuse detonators are more commonly used in R.A.R. because they are more convenient, and with them bombs may be fired from a moving vessel without an elaborate towing apparatus. Electric detonators are sometimes used for experimental purposes (see **664**).

Fuse detonators are small copper cylinders, closed at one end, partly filled with a charge of fulminate of mercury that is exploded by the train of sparks spit from a burning fuse inserted into the open end. Detonators are manufactured in two strengths, No. 6 and No. 8, the latter being the stronger. The No. 6 detonator is 1½ inches long and contains 1 gram of explosive; the No. 8 is 1⅞ inches long and contains 2 grams of explosive; both have the same diameter, approximately ¼ inch.

Fulminate of mercury is a very sensitive and violent explosive; it is readily detonated by friction, shock, sparks, or sulphuric or nitric acid. In its pure state it is only slightly soluble in water, but in a mixture, as used in detonators, moisture is absorbed readily and the sensitivity is decreased when it becomes damp.

Electric detonators are exploded by the passage of an electric current that heats and ruptures a wire bridge, which is inserted into the explosive charge, joining the two conductor wires. They, also, are made of fulminate of mercury, and in the same strengths as fuse detonators, i. e., No. 6 and No. 8. A number of different types of electric detonators are manufactured, but only a special waterproof type is suitable for use in water. The latter differs from other electric detonators in that it is made longer to allow more space for waterproofing compound, and the wires are copper and are coated with enamel so that if water penetrates the cotton insulation it cannot reach the copper. Electric connections should be made at the tinned ends, but if the wires have to be cut to shorten them, the enameled insulation as well as the cotton insulation must be scraped off. Electric detonators may be obtained with wire leads of various lengths from 4 to 20 feet, and longer lengths of wire may be obtained if ordered specially.

When ordinary electric detonators are fired by a current of about 1.5 amperes, there is a lag of 0.0073 second in the elapsed time from the application of the current to the rupture of the wire bridge and an induction period (the elapsed time from the rupture of the wire bridge to the explosion of the detonator) of 0.0069 second. The sum of these is a lag of 0.0142 second between closing the circuit and detonation, which is appreciable in experimental investigations. A special electric detonator (Du Pont "SSS"), developed for seismic use, should be used for experimental purposes. In this type of detonator the induction period is eliminated and the delay in rupture of the bridge is reduced to 0.0035 second when a current of 1.5 amperes is used. Increased amperage reduces the time delay considerably.

All detonators must be stowed in a safe place, as far removed from the magazine or the bomb locker on deck as convenient. They may be stowed in a watertight metal

box, secured to the rail in such a manner that it can be thrown overboard readily in case of fire or other danger. The box should be felt lined or otherwise cushioned on the bottom and all four sides to eliminate the possibility of shock. The fuse detonators must be kept in the tin box in which they are supplied, with the small square of felt covering them to protect them from the metal lid. Electric detonators should be enclosed in a soft cloth and protected with the same care as fuse detonators.

### 668. Fuse

Standard commercial, slow burning, waterproof safety fuse is used to fire the detonators in bombs used in R.A.R. It has a core of slow burning powder, either a free core or a solid core, in the center of several layers of jute or similar material, the outside of which is coated with a waterproofing compound. A number of different brands of safety fuse are manufactured for use under different conditions and in different areas. Most of the brands marketed on the Atlantic Coast are manufactured to burn at a rate of 1 foot in 30 seconds in air, but one sold under the trade name "Clover Brand," manufactured by the Ensign-Bickford Company of Simsbury, Connecticut, burns at the rate of 1 foot in 40 seconds in air. The latter is the rate of burning of the brands of safety fuse marketed on the Pacific Coast in 1939.

The manufacturers of safety fuse do not guarantee the burning rate, because altitude, weather conditions, care in handling, and other factors may affect the rate. Each coil of fuse for R.A.R. bombs should be tested, preferably in water, to determine the rate of burning before it is used. In water under the pressure at the depth of 5 fathoms, fuse will generally burn about one-third faster than in air.

Some brands of safety fuse are especially manufactured for use in water. It should be noted that, although these will burn in water, they will not withstand prolonged wetting, especially under pressure. The fuse that is selected for use in R.A.R. should, of course, be waterproof and burn at a slow rate, and preferably it should be of the solid core variety.

Fuse should be stowed in a cool dry place, at temperatures between 45° and 75° F. If a common salt shaker containing table salt is placed in the stowage place for about 72 hours and the salt remains dry enough to be shaken out at the end of this time, the place is sufficiently dry for stowage. Fuse deteriorates with age and not more than a 2- or 3-month supply should be purchased at one time. It should be left in its original container and should not be cut into short lengths until just before use, for if the powder grains fall out of the cut ends, lighting may be difficult and misfires may result.

### 669. Precautions in Handling Explosives

The general methods to be used and the precautions to be observed while handling explosives are described in **661** to **668** inclusive. The important **DONT'S** to be observed for safe handling of explosives, selected from the recommendations of the Institute of Makers of Explosives and amplified for special application to the use of explosives in R.A.R. are listed and **must be observed** for safety in handling explosives on board ship.

(1) **DON'T** stow explosives in a wet or damp place—they should be stowed where it is clean, cool, dry, and well ventilated.

(2) **DON'T** stow detonators in or near a magazine or locker containing other explosives.

(3) **DON'T** open cases of explosives in a magazine.

(4) **DON'T** use any metal tool for opening cases containing explosives—use only wooden wedges and wooden, fiber, or rubber mallets.

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(5) **DON'T** throw down packages of explosives, or slide them along deck or over each other, or handle them roughly in any manner.

(6) **DON'T SMOKE** while using or handling any explosive—smoking must be prohibited in the vicinity.

(7) **DON'T** permit matches in the vicinity while handling explosives.

(8) **DON'T** handle explosives near open lights, open fire or flame, or sparks.

(9) **DON'T** handle TNT with bare hands—rubber gloves or other methods of protection must be used.

(10) **DON'T** fill bomb containers in an inadequately ventilated place.

(11) **DON'T** leave packages of explosives unprotected.

(12) **DON'T** expose explosives or detonators to the direct rays of the sun.

(13) **DON'T** attempt to extract detonators from a box by inserting a wire, nail, or other sharp instrument.

(14) **DON'T** attempt to remove or investigate the contents of a detonator.

(15) **DON'T** carry detonators in the pockets of clothing.

(16) **DON'T** try to withdraw the wires from an electric detonator.

(17) **DON'T** tap or otherwise investigate detonators.

(18) **DON'T** investigate misfires in electric detonators—cut an unexploded bomb adrift without bringing it on board.

(19) **DON'T** stow fuse in a hot place. Heat may injure the fuse and cause the waterproofing material to damage the powder train.

(20) **DON'T** handle fuse carelessly in cold weather. When cold it is stiff and breaks easily. It should be warmed slightly before use.

(21) **DON'T** use short fuses. Cut fuse sufficiently long to allow time for the end to seal before the bomb is thrown overboard and to permit the bomb to sink to the desired depth of detonation. The rate of burning should be determined for each coil of fuse.

(22) **DON'T** cut fuse on a slant—cut it square across. At the beginning of bombing operations cut off an inch or two of fuse to ensure having a fresh end inserted in the detonator. See that the fuse is seated against the charge in the detonator before crimping.

(23) **DON'T** crimp detonators around the fuse with a knife blade or with the teeth—use only a suitable crimping tool.

(24) **DON'T** attempt to light fuse with burning paper or other inflammable material—use only an electric heating unit or other safe device (see **6841** and **6844**).

(25) **DON'T** use empty explosive boxes for kindling.

## 67. SHIP PERSONNEL AND EQUIPMENT

### 671. Personnel Organization

The organization and duties of the personnel of a hydrographic survey party using R.A.R. are entirely different from those required for other methods of control (see **142**, table 2, and **341**). In R.A.R. the data are available for use in plotting only after an appreciable length of time after the time of the position, and the operations and personnel are organized to reduce this interval to a minimum. Coordination and cooperation are essential and it is important that all personnel perform their duties with perfect timing.

For operations during daylight hours only, the personnel of a vessel are usually organized into two watches, each of which consists of an officer in direct charge of operations, a chronograph attendant, a recorder, a radio technician, and a bomber, in addition to the fathometer attendant, quartermaster, helmsman, and other members of the watch. For continuous operations on a 24-hour basis, personnel for three watches are required; the watch periods may be rotated daily, or as desired, so that the same personnel do not stand the same watches for extended periods of time. When sufficient experienced personnel are available, the officer-in-charge and the chronograph attendant, who is usually an officer, may exchange duties. At night, during fog, and during

generally reduced visibility, in addition to the usual bow lookout, an additional watch officer is required whose sole duty is to look out for the safety of the vessel.

Where R.A.R. shore stations are used, a radio technician is required at each station and, if living accommodations are not available near the station, an additional man is needed to serve as cook and helper.

An officer, stationed at the plotting table, is in direct charge of all operations, under the general supervision of the Commanding Officer. The plotting table should be located on the bridge so that the officer-in-charge may supervise the navigation of the ship, log readings, taking the soundings, etc. Where this is impracticable, the plotting is done in a drafting room and an additional watch officer must be stationed on the bridge to supervise the sounding, the observation of supplemental data, and the navigation, making such changes in course as are ordered by the officer-in-charge over the communication system.

### *6711. Officer-in-Charge*

The officer-in-charge plots the position of the ship after the time intervals have been obtained and have been relayed to him by the chronograph attendant over the communication system, or by messenger. The data are recorded by the officer-in-charge on Form 722, R.A.R. and Dead Reckoning Abstract (see **8312**), on which are also recorded other position data for temporary field use, when the form is used. From the R.A.R. data he plots the position of the ship, using the time or log distances between successive positions as a check. After the position is plotted, a change in course is ordered, if necessary. When time permits, the positions are inked on the sheet, after their accuracy has been verified. A carbon copy of the soundings, including the position numbers and times, is made by the recorder by inserting a narrow slip of paper and carbon paper beneath that part of the Sounding Record page. The soundings are reduced for predicted tide and the reduced soundings are inked on the boat sheet by the officer-in-charge as the carbon copies become available. An additional man may be required to reduce the soundings and record the data on the R.A.R. abstract if the interval between positions is short, but these duties can usually be performed by the officer-in-charge.

### *6712. Chronograph Attendant*

The chronograph attendant is stationed at the chronograph which must be located in or adjacent to the radio room. The officer-in-charge decides on the interval between positions and usually instructs the chronograph attendant to this effect. The latter then orders the bombs by a system of signal bells (**6741**) to the bombing station located on the afterdeck of the vessel. On some vessels the signal for the bomb may originate at the plotting station, or on the bridge. At the "bomb over" signal from the bomber, the chronograph is started and the chronograph attendant attends it while the returns are being recorded on the tape (see **6851**), measures the returns (see **6853**), and records them in the Bomb Record (see **8311**). He also times the ship's run from the "bomb over" signal to the explosion, unless this is automatically registered on the tape (see **6813**), and records it. He reports the results over the communication system to the plotting station where they are received by the officer-in-charge, who uses them to plot the position.

The general operations of bombing and receiving the returns are supervised by the chronograph attendant. He has direct supervision over the radio technician and the

bomber, but the interval of time between positions, known as the bombing interval, is decided by the officer-in-charge.

### *6713. Radio Technician*

The radio technician assigned to each watch is in charge of the instrumental equipment, under the supervision of the chief radio technician. He should see that all the required switches are turned on, that the radio receiver is properly tuned to receive the radio signals and aid, if possible, in the identification of the returns from the various R.A.R. stations. During excessive static he should be especially vigilant to see that the gain of the amplifier is properly adjusted to receive radio returns with a minimum of spurious marks on the chronograph tape. There should be a sufficient number of radio technicians so that there is one for each watch, in addition to the chief radio technician who should be free to maintain and repair R.A.R. equipment.

The radio equipment used in R.A.R. is highly specialized and, as the success of the method depends, to a large extent, on its satisfactory operation, it is essential that the radio personnel be of the highest type and thoroughly trained. They should have a basic knowledge of radio communication, but the specialized training can be obtained only by actual operation of the R.A.R. equipment under competent supervision. Graduates from good radio schools, or technicians who have been connected with commercial broadcasting or experimental investigation, are usually most satisfactory in R.A.R.

### *6714. Bomber*

One member of the crew is assigned as bomber for each watch, supervised by a chief bomber, who stands one of the watches and also has general charge of the preliminary preparation of the bombs, the care of the explosives, and their stowage. At receipt of the signal designating the size of bomb (see **6741**), the bomber selects the bomb, completes the final preparation (**6842**), and stands near the lighting unit ready to light the bomb at the signal. When the signal is received, he lights the bomb and throws it overboard, and as it strikes the water he gives the "bomb over" signal by means of a portable electric push button, which he carries in his hand. This signal is the official time of the position. It is received simultaneously on the bridge and at the chronograph station. The recorder on the bridge has the log read, and any other supplemental data are observed that are desired at the time of the position.

The assignment of members of the crew as bombers is very important. The ones selected preferably should have had considerable experience with explosives and should have a sound knowledge and an intelligent understanding of their use—the kind of knowledge that may be best gained by experience. An inexperienced man should always be given definite instructions before he is allowed to handle explosives and then should work under the supervision of a careful experienced man until he demonstrates that he can be relied on not to endanger himself or his shipmates. Men who, through ignorance, carelessness, or bravado, follow unsafe practices must not be allowed to handle explosives.

## 672. Ship Equipment for Radio Acoustic Ranging

The special electric equipment on the survey ship used for R.A.R. includes the hydrophone, radio receiver, chronograph amplifier, chronograph, break-circuit chronometer or criftig (**6734**), and communication system. Their coordinate functions from

the time a bomb explodes until the radio signals from the R.A.R. stations have been recorded on the chronograph are as follows:

The explosion of the bomb is received on the hydrophone and the signal is increased by an amplifier sufficiently to operate the stylus of a chronograph which makes a mark on a moving tape. The stylus circuit is then immediately connected either manually or automatically to the output of a radio receiver. Through this the radio signals from the distant R.A.R. stations are received and actuate the stylus, which marks each signal on the tape. During this period, from the time the bomb was thrown overboard until the reception of the last radio signal, regular time intervals are being marked on the chronograph tape by another stylus operated from a break-circuit chronometer or from the criftig. Thus the time intervals from the explosion of the bomb to the reception of the various radio signals may be measured on the tape.

A buzzer or other signal system is used to signal between the several stations so as to coordinate their respective functions. A communication system between the chronograph station and the plotting room is also necessary.

Where R.A.R. shore stations are used, the R.A.R. equipment of the survey ship includes a medium-power short-wave transmitter to communicate with these stations.

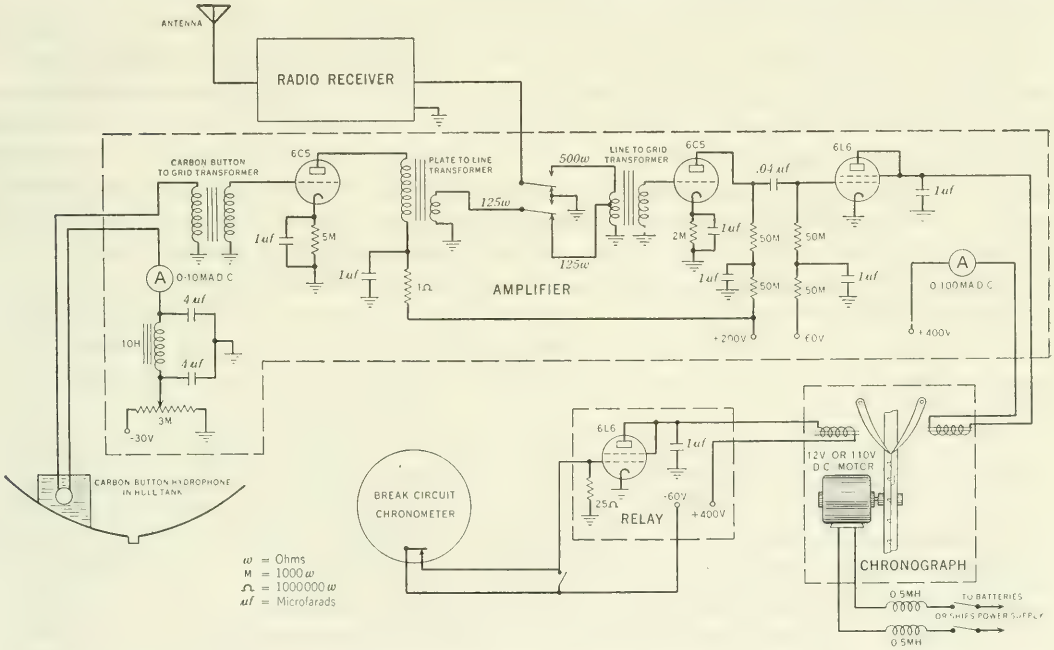


FIGURE 140.—Circuit diagram of R.A.R. equipment for survey vessel.

### *6721. Hydrophone*

The hydrophone used on the vessel for the reception of the bomb signal may be either the Submarine Signal Company watch-case type 134*E*, the rubber rat (K-tube unit), or the tuned hydrophone 341*A*, all of which are described in **5213**. Each of these uses a carbon-button element. The hydrophone is installed in a water-filled tank which is fastened to the inner side of the hull of the ship. A suitable tank is the Submarine Signal Company 356*B* which is used for the 312 Fathometer. This hydrophone, as for echo sounding, should be located where undesired noises will be received at a minimum, as described in **541** (see also **5148**).

### *6722. Radio Receiver*

Any one of a number of good communication receivers may be used for the radio receiver shown in figure 140. Commercial receivers, such as those made by Hammarlund Manufacturing Company, Inc., of New York, The Hallicrafters, Inc., of Chicago, and National Company, Inc., of Malden, Massachusetts, are used exclusively for this purpose by the Coast and Geodetic Survey.

The radio receiver should include the following features to be satisfactory for use in R.A.R.:

(*a*) It must be suitable for marine use.

(*b*) It must be capable of withstanding excessive vibrations without damage, detuning, or modulating the output signal.

(*c*) After the warm-up period, the tuning should remain essentially constant, irrespective of moderate voltage, temperature, or humidity changes.

(*d*) It must be sufficiently sensitive.

(*e*) It must possess high image rejection.

(*f*) It should contain a crystal intermediate-frequency filter.

(*g*) The frequency range of the receiver must include all the frequencies used in R.A.R.

(*h*) The receiver tuning must not be critical.

(*i*) The audio-frequency power output should be at least 2 watts.

(*j*) It must contain an adjustable intermediate-frequency beat oscillator.

Some of the models of radio receivers made by the above-mentioned companies meet practically all the listed requirements. To comply with most of these requirements the receiver must employ a superheterodyne circuit. There should be one or two stages of radio-frequency amplification to aid in amplification, image rejection, and increased signal-to-noise ratio. The intermediate-frequency amplifier should contain two or more stages. The width of the intermediate-frequency band should be from 5 to 8 kilocycles. The band width of the intermediate-frequency crystal filter should not exceed 100 cycles, in order to eliminate as much interference as possible.

Frequencies used by the Coast and Geodetic Survey for R.A.R. range from 2.5 to 4.2 megacycles (see **6442**). The receiver must cover this range, in fact most of the receivers used for R.A.R. cover a range from broadcast frequencies to frequencies as high as 42 megacycles.

It is desirable to have both radio-frequency and audio-frequency gain controls. Most commercial communication receivers are also equipped with automatic gain control but this feature is seldom used in R.A.R., the gain being adjusted manually. The tuning control should be provided with band-spread features so that a critical adjustment will not be required in tuning. The dial of the receiver should be calibrated to show accurately the frequency at which the receiver is tuned.

The receiver should have terminals for both headphones and loud speaker. It has sometimes been found convenient to use the output voltage at the headphone terminals to operate the chronograph amplifier; therefore, the impedance at the headphone terminals and of the chronograph amplifier input should be identical. The chronograph amplifier input for the circuit in figure 140 is 500 ohms. If the output impedance of the receiver is either one-third or triple that of the chronograph input impedance, an intermediate matching transformer should be used. An alternative method is to change either the receiver's output transformer or the input transformer of the chronograph amplifier so that their impedances are properly matched.

Most of the receivers used on vessels of the Coast and Geodetic Survey are operated on 110-volt 60-cycle current

### *6723. Ship's Antenna for R.A.R.*

Because of the low radio power radiated by sono-radio buoys, the receiving system on the survey vessel must be very efficient. In this respect the ship's antenna used for receiving the radio signals from the sono-radio buoy is very important. An ideal system would be a vertical antenna one-quarter to one-half wave length long, with no marked directivity characteristics in the horizontal plane. However, few survey vessels have masts tall enough to support such an antenna, and the influence of metal of the vessel in the field of the antenna usually makes it somewhat directive. Much can be done, however, to make the antenna approach the desired characteristics. Where space permits, the length of the antenna should be one-quarter to one-half of the wave length used by the sono-radio buoy, even though all or part of the antenna is sloped. The antenna should be kept as far as practicable from stays, rigging, smokestack, and other antennas.

The antenna wire should be strong and flexible, and suitable for shipboard use. A stranded 7 by 22 phosphor-bronze wire is a preferred type. Insulators of a high quality, such as pyrex 7½-inch, should be used to support the antenna. Two or more such insulators should be used at each point where any are needed, to increase the leakage path. The antenna should be kept taut at all times to prevent its swinging.

The following test may be made to determine whether an antenna has the desired directivity characteristics: Tune in a distant radio signal of about the same frequency as that of the sono-radio buoy. The ship should then be turned slowly through 360° while the strength of the radio signal is noted on some metering device incorporated in or attached to the receiver. The antenna can be considered satisfactory if the minimum signal strength observed is not less than one-half the maximum observed.

If the test shows that the antenna is unsatisfactory, the entire system should be carefully overhauled, and reinstalled if necessary, bearing in mind the points emphasized here.

### *6724. Chronograph Amplifier*

Numerous types of audio amplifiers are used by the Coast and Geodetic Survey for the operation of the chronograph. Their performance is essentially the same; they differ only in design. Only one type of amplifier which has given good results will be described. A circuit diagram of this chronograph amplifier is included in figure 140.

The sensitivity of this amplifier is about medium and its frequency characteristics are those of any fairly good audio amplifier. The last two tubes of the amplifier operate on receipt of either the bomb or radio signals, whereas the first tube amplifies only the bomb signal. Located between these two sections of the amplifier is a switch, known as the *hydro-radio* switch, which is intended for switching the last two stages that operate the signal stylus of the chronograph either to the output of the hydrophone amplifier tube or to the output of the radio receiver. The final tube in the chronograph amplifier is a type 6*L*6 beam power tube, triode connected. The plate circuit of this tube is connected to the signal stylus magnet. This tube is biased to cutoff so that only the positive peaks of the signals cause the plate current to flow. A filter in the plate circuit removes the audio-frequency component leaving only the envelope of the audio-frequency signal. A milliammeter in the plate circuit of the type 6*L*6 tube gives the integrated value of its plate current caused by the bomb or radio signal. This meter should be located where it can be observed by the radio technician or chronograph attendant or both; it gives an indication of signal intensity. Preceding the type 6*L*6 tube is a type 6*C*5 triode tube which is arranged to operate as a class A amplifier. A line-to-grid transformer with 125- and 500-ohm primary taps operates into the grid of the type 6*C*5 tube. The 125-ohm primary tap is connected through a switch to the 125-ohm secondary of a plate-to-line transformer, which is connected in the plate circuit of the hydrophone amplifier tube. The 500-ohm

tap of the line-to-grid transformer connects to the output of the radio receiver by means of separate contacts on the above-mentioned switch.

When the hydro-radio switch is in the position to receive the bomb signal, the output of the radio receiver is short-circuited; and when the switch is in the position to receive the radio signal, the output of the bomb amplifier is short-circuited. The short-circuiting of one circuit while the other is in use is to prevent cross operation between circuits. A double-pole double-throw switch that can be operated rapidly can be used; but a preferable arrangement is a telephone-key switch connected to operate for the reception of the bomb signal when held down, but which, when released, will spring back to normal position and transfer the circuit to the output of the radio receiver. Whatever arrangement is used, the whole switching operation should require no more than a half second, for the speed with which this switch can be operated determines the minimum time after the bomb explosion that a radio signal can be recorded on the chronograph. The manually operated switch described above may be replaced by a relay which automatically switches to the output circuit of the radio receiver as soon as the bomb signal is received, as in the Dorsey chronograph (see **6733**).

The gain control for bomb reception is by regulation of the current flowing to the carbon button of the hydrophone, a d-c milliammeter indicating the amount of current flowing to this unit. Once the proper value of gain has been determined, readjustment is rarely required. The gain for the radio signal is adjusted by the controls which are part of the radio receiver.

## 673. The Chronograph

A chronograph is a graphic-recording time-measuring device, used in R.A.R. to measure the time intervals between the bomb explosion and the reception of the radio signals from the R.A.R. stations. The record is made on a narrow wax-coated paper tape by two sharp-pointed electromagnetically operated styluses. The tape passes at a constant rate under the styluses which are adjusted so that their marks coincide to mark a single line down the center of the tape when they are in an unactuated state. (See fig. 141.) When actuated the two styluses move in opposite directions from the center toward the edges of the tape, the maximum amplitude of motion being about 3/16 inch. After operation, a stylus is returned to normal position by means of a spring. The mark on the tape where the stylus leaves the centerline is used in scaling all time measurements. One stylus marks the time and is known as the timing stylus, and the other, operated by the chronograph amplifier, is known as the signal stylus. The method of scaling the tapes from a Gaertner chronograph is described in **6853**.

*a. Chronograph tape.*—The tape is a narrow red- or black-bodied paper, one surface of which is covered with a thin white wax coating. The melting point of the wax is sufficiently high to withstand tropic temperatures unless the tape is exposed directly to the sun's rays. This tape comes in 300-foot rolls, wound on a wood center about 1¼ inches in diameter with a ½-inch centerhole. The tape is about ½ inch wide and 0.002 inch thick. One roll of tape is sufficient for about 1 hour's continuous operation on the Gaertner chronograph.

### *6731. Gaertner Chronograph*

Most of the chronographs used in the past in R.A.R., and sometimes still used by the Coast and Geodetic Survey, were made by the Gaertner Scientific Corporation

of Chicago, Illinois. All parts of this instrument are mounted on a heavy metal base. On one end of the base is a spool which holds the chronograph tape. Directly in front of the spool are the magnets for operating the styluses; these magnets are mounted on a hinged plate so that the stylus points may be raised while changing the tape. The tape passes under the hinged plate and across a guide plate and thence between two rollers by which it is drawn. The points of the two styluses contact the surface of the tape where it passes over the guide plate. The rollers that draw the tape are driven by a small electric motor which is coupled to the shaft of one of the rollers through reduction gears. Most of these instruments are of the d-c type operated from 12 volts, but a few contain 110-volt d-c motors. A lever is provided to separate the two rollers so that the tape can be stopped without stopping the motor, and to facilitate the rethreading of the tape. The styluses may be adjusted as to pressure on the tape surface, amplitude of motion, and position of the stylus point on the tape. The speed of the chronograph tape is about 2 cm per second.

The d-c resistance of the signal stylus magnet on most of these chronographs is about 800 ohms, and that of the timing stylus magnet is usually about 5 ohms. On some chronographs the magnets and styluses supplied originally have been replaced with redesigned Baldwin piano units to which light styluses have been attached. Such an alteration provides a quicker acting stylus and minimizes mechanical lag. Rochelle salt crystals have also been used to actuate the styluses.

A Gaertner chronograph of more recent design is also used on some vessels of the Coast and Geodetic Survey. Its principles are the same, the major differences being in mechanical design and the use of a 110-volt 60-cycle synchronous motor to move the chronograph tape.

### *6732. Break-Circuit Chronometer*

A break-circuit chronometer is used with the Gaertner chronograph to actuate the timing stylus once each second. It is like any ship mean-time chronometer, except that it is equipped with electric contacts operated by the chronometer movement. These electric contacts are opened once each second for about one-tenth second. The length of the break is adjustable, but it should not be attempted on board ship. The operation of these contacts, when connected to the proper circuits, produces the time offsets on the chronograph tape. These contacts are delicate and the current through them and the voltage across them must be kept at low values. Some type of relay circuit should be used between the chronometer and the chronograph timing stylus magnet; an electrically operated relay may be used, but a vacuum-tube circuit such as is shown in figure 140 is preferable.

### *6733. The Dorsey Chronograph*

The Dorsey chronograph was designed by the Coast and Geodetic Survey to provide more accurate timing of R.A.R. distances, and to be read without a glass scale (**4825**). It uses the same tape as the Gaertner chronograph, but the speed of the tape is two and a half times as fast, a time offset is marked each tenth second, and the seconds are numbered.

This instrument uses two styluses, one which marks tenths of seconds and one which records the bomb and radio return signals. The speed of the tape is about 5 cm per second, so that the offsets marked at each tenth second are about 5 mm apart, enabling the estimation of the time intervals to 0.01 second without using a glass scale.

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Each fifth offset is marked longer than the others and at each tenth offset (each second) a figure is printed, starting with 0 at the first offset after the receipt of the bomb signal. These figures are printed 0 to 9 and then repeated so that the time intervals may be rapidly read.

*a. Operation.*—The bomber is signaled in the regular manner to fire a bomb. A switch on the chronograph amplifier is closed, so that the bomb explosion may be received on the chronograph. When the bomber signals that the bomb has struck the water, the signaling current also operates a relay in the amplifier which automatically starts the 60-cycle motor of the chronograph. This sets the tape in motion and the timing stylus begins marking tenth seconds. When the bomb explodes and the sound reaches the hydrophone, the signal stylus immediately marks on the tape and at the next tenth second a clutch releases the printing wheel so that the numeral 0 is printed opposite this tenth-second mark. Thereafter each fifth offset is made longer by an index wheel, also released by the clutch. Another relay automatically switches the amplifier from the bomb hydrophone to the radio receiver (see **6724**).

The R.A.R. time interval to be used in plotting is then all of the numbered seconds, plus the fraction of a tenth before the zero, plus the fraction of a second after the last printed number, plus the ship's run correction (**6853** (*d*)). This latter is found from the elapsed time recorded on the tape prior to the bomb signal. The chronograph attendant does not have to time this interval by clock or watch, as is the case with the Gaertner chronograph (see **6843***a*).

A switch on the chronograph amplifier cabinet is then opened and the clutch reset, ready for the next bomb.

### *6734. The Criftig*

In order for the Dorsey chronograph to function as a precision instrument it must be supplied with controlled 60-cycle alternating current and tenth second impulses of high accuracy. This is obtained from electric circuits starting with a piezoelectric crystal with a frequency of 100,000 cycles per second, adjustable within a narrow range. As developed by the Coast and Geodetic Survey, these circuits, by fractional frequency division, give a crystal-controlled current for the time generator. The arrangement is abbreviated *criftig*. In this the 100 kc is first divided by four, then by five, and again by five, giving 25 kc, 5 kc, and 1 kc. The latter operates a 1,000-cycle synchronous motor at a constant speed of 10 revolutions per second. The shaft of the motor also carries the rotor of a 60-cycle generator and a single rotating arm which passes near the pole pieces of a polarized electromagnet once each revolution, producing the 10 pulses per second.

Clocks on the ship's bridge and in the radio room are operated from the criftig and, by daily comparison with the radio signals sent out by the National Bureau of Standards, the rate of the crystal may be adjusted to a value so that the clocks give time which is seldom in error by as much as 0.1 second.

A special chronograph amplifier is required. It drives the 60-cycle synchronous motor, amplifies the 0.1 second pulses to the timing magnet, and amplifies the bomb signal. By the arrangement of certain thermionic tubes and circuits, this amplifier produces a sequence of events permitting the reception of bomb signals and radio returns almost automatically. No relay action is involved in the timing of the return signals so that no lag in time is introduced.

### 674. COMMUNICATION SYSTEM

To coordinate the operations at the various stations on a vessel using R.A.R., an adequate communication system is essential. This system includes interconnected electric bells, located near the chronograph attendant and on the bridge. The bomber, at his station near the stern of the vessel, may ring these simultaneously by means of a portable push button which he can carry in his hand while throwing the bomb overboard. Another bell is located at the bombing station, connected to be rung either by the chronograph attendant or from the bridge, depending on who orders the bombs.

If the chronograph station is remote from the plotting station and if the latter is not located on the bridge, a communication system must be provided between the three, so that data and orders may be rapidly and accurately transmitted. The R.A.R. time intervals for each position must be transmitted from the chronograph station to the plotting station with a minimum of delay and, where the plotting is not done on the bridge, orders relative to the navigation must be transmitted from the officer-in-charge to the watch officer on the bridge. Speaking tubes or telephones may be used for this purpose, but instruments used for interoffice communication are much more satisfactory. The latter are made under various trade names by a number of manufacturers of electric equipment, but any selected should be adapted for use on shipboard. A loudspeaker type of unit is desirable, arranged so that a lever is pressed to talk and released to listen. This leaves both hands free for copying any transmitted data.

#### *6741. Bombing Station Signals*

In Radio Acoustic Ranging (R.A.R.) bombs of various sizes are required, depending on the distances from the R.A.R. stations and other factors which influence the transmission of sound. The chronograph attendant is able to judge the size of bomb required by observing the character of the radio returns from the stations. The same size of bomb will often be used continuously for a considerable period of time, but it is occasionally necessary to change; and a system of bell signals should be provided to notify the bomber of the size of bomb wanted at each position, and when to light the bomb and throw it overboard.

The signals are given by the chronograph attendant, or from the bridge, by ringing a bell at the bombing station. The signals for bombs of different sizes may be various combinations of long and short rings, a long ring being approximately three times the duration of a short ring. The following signals are recommended:

| *Type of bomb* | *Signal* |
|---|---|
| Single detonator | Five short rings. |
| One-quarter pint | One long ring. |
| One-half pint | Two long rings. |
| One pint | Three long rings. |
| One quart | One long and one short ring. |

For bombs of other sizes, suitable signals may be arranged.

The clock at the chronograph station should be synchronized with the clock used for sounding. At 1 minute before a position the bomber is given the signal designating the size of bomb desired. The bomber answers this signal immediately with two long rings, indicating that the signal has been received and understood; this acknowledging signal is received both by the chronograph attendant and on the bridge where it serves as a stand-by signal for any observations to be taken on the position. Ten or 15 seconds before the position the bomber is notified to light the bomb, by one extra-

long ring. This signal must be given a sufficient number of seconds in advance of the desired time of position to allow for lighting the bomb and throwing it into the water. This time interval will vary, depending on the length of fuse and the alacrity of the bomber. Just as the bomb strikes the water, the bomber signals with one long ring. This is the official time of the position. The signal is received at the chronograph station where the chronograph is started, and on the bridge where it serves as the "mark" for any observations which are to be made on the position.

## 68. R.A.R. OPERATIONS

### 681. R.A.R. Positions

The essential difference between a hydrographic survey controlled by R.A.R. and one controlled by other methods is the manner in which the positions of the survey ship are determined. The positions are not based on sextant angles or other visual observations, but are determined by plotting graphically the distances of the ship from two or more R.A.R. stations whose positions are known. The distances are derived from measurements of the travel times of subaqueous sound from a source of sound near the ship to receiving units at the several R.A.R. stations. The various operations involved in obtaining an R.A.R. position are necessarily performed at several different places on the ship, and the procedure is, therefore, more complicated than for any of the other methods described in section **33**. The positions must be anticipated and preparations made, and the position data are not available for plotting until about 5 minutes after the time of the position, all of which affect the conduct of the operations.

#### *6811. Time of Position Data*

The official time of an R.A.R. position, and the time to be recorded in the Sounding Record and Bomb Record, is the exact time that the bomb strikes the water when it is thrown overboard—*not* the time of its explosion (see **6853** (*d*)). The position that will be determined is that of the bomb—not that of the vessel at the time of bomb explosion.

Positions should be obtained at equal intervals and on the minute or half-minute, if practicable. This is not essential, but it facilitates spacing recorded soundings, which are generally recorded on the minute or fractions thereof. With experienced personnel, bombs may be timed to strike the water within a few seconds of a desired time without danger, in which case the positions may be recorded on the even time interval.

The clock at the chronograph station should be synchronized with the sounding clock so the times of positions recorded in the Sounding Record and the Bomb Record will be identical. If they are not automatically synchronized, they should be checked frequently to ensure that the two clocks are always within 2 or 3 seconds of one another.

The sounding on the position must be obtained prior to the explosion of the bomb. A sonic oscillator must be turned off while the bomb explosion is being recorded, because the oscillator signals would record on the tape. Furthermore, the explosion of a bomb causes a multitude of sound waves which are registered on any echo-sounding instrument and which obliterate the echo soundings for an appreciable length of time.

Log readings, revolution counter readings, bearings, sextant angles, and any other supplemental position data are observed at the signal from the bomber which indicates that the bomb has struck the water. These supplemental data must be recorded in the Sounding Record. If the R.A.R. abstract is used (see **8312**), the time intervals are recorded in it when they are received from the chronograph attendant, and any of the supplemental data needed for plotting on the boat sheet are also recorded in it.

### *6812. Frequency of R.A.R. Positions*

The frequency of positions in R.A.R. surveys, like surveys controlled by other methods, depends on a number of conditions which are discussed in **3313**. The maximum frequency of R.A.R. positions is limited by the time required to obtain the R.A.R. distances from the chronograph tape and to plot the position on the boat sheet, this generally requiring from 3 to 5 minutes depending on the distances involved and the adroitness of the personnel. Nothing is gained by taking R.A.R. positions faster than the data can be computed and plotted.

Depending on the current, R.A.R. surveys on the Atlantic and Gulf Coasts can be satisfactorily controlled by positions every 5 or 6 minutes in areas of moderate depths when surveyed on a 1: 80,000 scale or larger, and every 8 or 10 minutes in deeper offshore areas surveyed on a scale of 1:100,000 or smaller. Positions are often taken still less frequently in offshore areas where large cast-iron bombs are required or when it is necessary to conserve bomb materials. On the Pacific Coast and in Alaska waters, offshore surveys have been satisfactorily controlled with positions obtained at intervals as long as 30 minutes, but the fixed positions must be supplemented by adequate dead-reckoning data.

Accurate dead-reckoning data must be recorded for use in conjunction with R.A.R. surveys and it is frequently advantageous to identify some of the intermediate points between bombs as positions (see **3312**). In addition to those at regular intervals, where practicable, R.A.R. positions should be taken at the following times:

(*a*) At the beginning and end of each sounding line, except at a 180° change in course where the beginning of the new line is so close to the end of the previous line that time does not permit two R.A.R. positions so close together. In the latter case the position at the end of the first line should be determined by dead reckoning so that an R.A.R. position can be obtained at the beginning of the new line. This fixes a position on the new line as soon as possible so that the hydrographer may change the course, if necessary, to make the track of the vessel coincide with the proposed line.

(*b*) At all major changes in course. In general, changes in course of 3° or less need be merely recorded in the Sounding Record with the time of the change, changes in course from 3° to 10° should be recorded as positions and given numbers, but changes in course greater than 10° should be fixed by R.A.R. positions.

(*c*) At all changes in speed.

### *6813. Obtaining an R.A.R. Position*

Assuming that an R.A.R. position is desired at 14:18, either because of the regular interval between positions ordered by the officer-in-charge or because he has specifically notified the chronograph attendant that a position is desired at that time, the following sequence of events occurs (see also **3442**):

At 14:17, one minute before the position is desired, the bomber is signaled by bell to indicate the size of bomb desired. The chronograph attendant then tests the chronograph to make sure that it will operate satisfactorily and that sufficient chronograph tape remains on the roll, and sees that the radio technician has the receiver turned on and properly tuned.

The bomber acknowledges the above signal with a two-bell signal which is received at the chronograph station and on the bridge. This indicates that the signal has been received and understood by the bomber and notifies the bridge personnel that an R.A.R. position is to be expected on the next even minute. The bomber selects a bomb of the size desired, inserts the fuse, and prepares it for lighting and, with bomb and push button in hand, stands by the lighting element ready to light the bomb when the next signal is received.

Ten to 15 seconds before 14:18, the bomber is notified by one long bell signal to light the fuse, preparatory to throwing the bomb into the water.

As soon as the bomber judges that the fuse is burning internally (see **6844** and **6845**), and not later, the bomb is thrown overboard and as it strikes the water the bomber signals with one long bell. This signal is received at the chronograph station and on the bridge. The time of the signal is recorded as the official time of the position. A sounding is taken, the log is read, and any other observations are made at this time; changes in course or speed are also made; and all are recorded in the Sounding Record.

When the "bomb over" signal is received at the chronograph station, the chronograph is started and the *hydro-radio* switch (**6724**) is held in position so that the bomb explosion will be registered on the chronograph tape. The time in seconds between the "bomb over" signal and the explosion is determined by a stop watch, from the second hand of a clock, or from the tape of a Dorsey chronograph (see **6733***a*). This time interval is recorded in the Bomb Record (see **6843***a*). The record of the explosion on the tape of a Gaertner chronograph is identified by a pencil mark near it.

Immediately after the explosion has been registered on the chronograph tape, the hydro-radio switch is released so that it is in position to allow recording of radio signals. The chronograph continues to run until the radio signals from all of the R.A.R. stations have been received and recorded on the tape. As each return is received and heard in a loud speaker, it is also identified on the tape by a pencil mark nearby. After the last radio signal has been received, the chronograph is stopped and the tape with the record is torn off.

The various time intervals required for determining the elapsed time to each station, for use in plotting, are then taken from the tape or computed, in accordance with **6853**, and entered in the Bomb Record.

As soon as the elapsed times have been accurately determined they should be transmitted to the officer-in-charge at the plotting station. Let us suppose that the number of the position is 89 and that returns were received from three R.A.R. stations, designated as ESAU, DAGO, and GOBY, and that the elapsed times to them, as identified by the chronograph attendant, are 8.56, 19.35, and 27.97 seconds respectively. The data should be transmitted approximately in the following manner:

The CHRONOGRAPH ATTENDANT calls the plotting station and after an acknowledgment, or over the loud-speaker system, says: "Bomb at fourteen eighteen."

The OFFICER-IN-CHARGE replies: "Position eighty-nine at fourteen eighteen." This enables the chronograph attendant to record the correct position number in the Bomb Record and on the chronograph tape.

CHRONOGRAPH ATTENDANT: "Position eighty-nine; ESAU eight fifty-six, DAGO nineteen thirty-five, GOBY twenty-seven ninety-seven."

The OFFICER-IN-CHARGE repeats the elapsed times to the chronograph attendant for verification.

The elapsed times to the various R.A.R. stations should be transmitted to the plotting station in the order of their length, the shortest being transmitted first. This is the natural order of scaling or reading the radio returns from the chronograph tape, and a little time is saved in making the settings of the fixtures on the beam compass.

After the elapsed times have been received at the plotting station, they are plotted graphically on the boat sheet using the most probable velocity of sound, and the position is determined.

Occasionally, at the chronograph station, a radio return from an R.A.R. station may be improperly identified, a false mark may be mistaken for a radio return, or an

error may be made (see **6852**). The chronograph attendant should be notified of any such error as soon as it is discovered at the plotting station and should be requested to check the questionable data, so that appropriate corrections may be made in the plotting and in the Records.

### *6814. The Bisectrix*

Between the positions of any two R.A.R. stations there is a line, known as the bisectrix, near which the radio returns from the two stations will be received so nearly simultaneously that it will be difficult to identify the station from which each was received. The officer-in-charge should avoid, so far as possible, obtaining an R.A.R. position near a bisectrix.

The bisectrices between all R.A.R. stations should be shown on the boat sheet by drawing perpendiculars at the midpoints of the lines joining the stations. When the officer-in-charge knows that a position at the regular time interval would plot near a bisectrix, he should advance or delay it enough to ensure that both of the returns will be received and can be identified. The officer-in-charge should also notify the chronograph attendant in advance which station, of two that will be received almost simultaneously, should be received first.

It is possible to reduce the lengths of the radio signals from the R.A.R. stations so that returns from two or more stations may be recorded within a few tenths of a second of one another (see **6432**).

### *6815. Trial Position*

Trial positions are frequently needed in maneuvering the vessel to the proposed line at the beginning of operations, and are a necessity at the beginning of operations after drifting at sea during the night. Trial positions where the dead-reckoning position is not even approximately known are sometimes difficult to plot because of the difficulty of identifying the R.A.R. stations. In such a case each R.A.R. distance should be trial plotted from each R.A.R. station, and an intersection found where the sounding at the time of the trial position agrees with the depths on the boat sheet. If only two returns are received at a trial position, and sometimes even where three or more returns are received, the plotted distances will intersect at two or more positions, of which selection can be made only by a verification of the depth.

Trial positions need not be recorded in the Bomb Record, nor in the R.A.R. abstract unless desired, for a permanent record of them is not required.

### *6816. Additional Data From Shore Stations*

Where R.A.R. shore stations are used, the radio technician on board the vessel should call each shore station by radio after each position to ascertain the intensity of the bomb sound as indicated on the milliammeter in the output circuit of the amplifier. This reading is a comparative measure of the intensity of the sound arriving at the hydrophone and, together with the size of the bomb and distance from the station, forms a valuable record that may be used to determine the sizes of bombs needed under various conditions. These data for each station should be recorded in the "Remarks" column of the Bomb Record. (See **641**.)

## 682. PLOTTING R.A.R. POSITIONS

The data from which an R.A.R. position is plotted are the elapsed times required for subaqueous sound to travel from the position of the explosion to the several R.A.R.

stations. The elapsed times must be used as distances in order to plot them on a hydrographic sheet, and for this purpose the velocity of sound in sea water must be known. The distances from the stations may be plotted graphically by several different methods, the position sought being at the intersection of the distance arcs (see **7631**).

During the survey the positions need to be known as quickly as possible, so that the ship may be maintained on the proposed line. Therefore, for the boat sheet a rapid method of plotting is required—extreme accuracy is not essential so long as complete coverage of the area is ensured.

For the smooth sheet the converse is true, the positions must be plotted as accurately as practicable and speed is not especially important. At this time better values of the velocity of sound to be used will have been determined and the positions can be more accurately plotted.

There are several general methods which may be employed in plotting R.A.R. positions. The elapsed time to each station may be converted into distance from an R.A.R. velocity scale (**4824**), and the distances plotted on the sheet with a beam compass. This method is generally used for plotting on the boat sheet in areas where different velocities of sound must be used.

Circles representing intervals of distance from the R.A.R. station may be drawn on the sheet and the distance from each station may be plotted by increments added to, or decrements subtracted from, the nearest circle representing the appropriate distance from the station. The circles may be drawn in even multiples of distance in meters or they may be drawn in distances representing even multiples of travel time at a selected velocity (see **7341**). Positions can be plotted more rapidly from circles representing seconds of travel time, and this method is used for plotting the positions on the smooth sheet (see **763**).

### *6821. Plotting Positions on the Boat Sheet*

After the elapsed times have been received from the chronograph station they are used to plot the position of the bomb explosion (see **6811**). If distances in meters are used for plotting, the elapsed times are converted into distances on an R.A.R. velocity scale, using a beam compass with the fixtures fitted to a suitable length bar. The distance from each station is plotted as a short arc near the estimated position on the boat sheet. The position is determined from the intersection of the distance arcs from two or more stations.

The approximate velocity of sound must be known before positions can be plotted on the boat sheet. Apparent horizontal velocities (**6351**), determined from tests made over distances measured by taut wire or from tests at positions fixed by sextant angles, are generally used for plotting during the survey. Where the apparent horizontal velocity is not known, or is not applicable, velocity calculated from the physical characteristics of the water, as explained in **6343**, may be used. (See also **636**.)

### *6822. Plotting a Position With One Distance Arc*

Occasionally a return is received from only one R.A.R. station, which, of course, will not fix the position. If this one distance arc intersects the sounding line at an angle greater than 45°, the position may tentatively be assumed to be at its intersection with the course from the preceding position. If the distance arc intersects the sounding line at an angle less than 45°, the position should be assumed to be at its intersection with the corrected log distance plotted as an arc from the preceding position.

Unexpected current, or a sudden change in current, may occur to affect the accuracy of a position based on one R.A.R. distance. All such positions must be considered tentative until after they have been verified by dead reckoning between well-fixed positions before and after them.

### *6823. Positions Near a Bisectrix*

Where it is practicable to do so, the hydrographer should avoid obtaining an R.A.R. position near the bisectrix between two stations (see **6814**). In such a case it is difficult for the chronograph attendant to identify the returns from the two stations and an erroneous identification may be made, resulting in some cases in an erroneously plotted position and even causing the hydrographer to change course on a false assumption.

Where a position occurs near a bisectrix, the distance arc, if only one return is identifiable on the tape, should be plotted from both of the stations in an effort to decide from which of the two stations the return was received. Sometimes the station may be identified from a knowledge of the dead-reckoning position, but where the position is nearly on a bisectrix the identification is always doubtful, to say the least.

It is sometimes necessary to anticipate such a situation and change the ship's course away from a bisectrix so as to be sure which one of two stations will be received first.

### *6824. Relative Strength of Positions*

The strength of a position located by two or more R.A.R. distances depends theoretically on the angle of intersection of the distance arcs. Assuming that a correct velocity of sound has been used or that the time intervals have been converted into accurate horizontal distances, the strongest positions are those where the distance arcs intersect approximately at right angles, and the more acute the angle of intersection becomes, the weaker the position is. Where the distance arcs are nearly parallel, the position is generally located very accurately in a direction perpendicular to the arcs, but very weakly in a direction parallel to the arcs. Such intersections generally occur at extreme distances from the R.A.R. stations and are to be expected near the offshore limits of offshore surveys. To fix positions satisfactorily in such areas, the R.A.R. distances must be supplemented by dead-reckoning data.

In R.A.R. surveys, distance arcs are occasionally plotted with data received from two stations which are nearly on range (in the same direction, or in opposite directions) with the position, so that the arcs plot nearly parallel to each other. If the arcs coincide at the position, it is an indication that the correct velocity of sound has been used, and another distance arc intersecting these two approximately at right angles will give a strong position. In boat-sheet plotting, the arcs from stations on range with the position seldom do coincide because a preliminary value of the velocity of sound is used, and generally, the position must be assumed to be between the two arcs, on a third intersecting arc or at a position indicated by the dead reckoning.

Sound is transmitted through sea water along a path which may vary for different distances and different depths of the water (see section **62**). If one of the distances of an R.A.R. position differs considerably from the others, it can seldom be combined satisfactorily with them if the same velocity is used for all the distances unless the elapsed times are first corrected for the paths of the sound waves (see **636**). A similar discrepancy may be expected if the path of the sound wave to one R.A.R.

station passes through extremely deep or very shoal water as compared to that traversed to the other stations.

The sound wave, in traveling an extremely short distance, may follow a direct path, but over a long distance it is apt to be refracted and reflected a number of times, thus making the travel time of the sound wave longer than it should be in proportion to the horizontal distance. Similarly, the depth of the water traversed and the temperature gradient affect the travel time of the sound wave. It is apparent, therefore, that an elapsed time under varying conditions is not exactly proportional to the horizontal distance, although this latter is what is needed for plotting. Combinations of distance arcs, where the above conditions vary extremely, will invariably plot erratically if the same velocity of sound is used for all of them, and in such cases greater weight should probably be given to the results from the nearer stations.

If the same velocity of sound is used throughout an area, and the elapsed times are uncorrected for the path of the sound wave, positions at a considerable distance from the stations are likely to be incorrect even though the distances seem to be in agreement. In such cases the stations are generally all in approximately the same direction from the position and the distance arcs intersect at acute angles, the depths are likely to be greater than average, and the temperature gradients will probably be such as to cause excessive refraction and numerous reflections. The apparent position will be in error, for the true position will be nearer to the stations by some amount nearly proportional to their distances from it. Such displacements, although known to exist, are difficult to correct, because of the many variable factors that influence the propagation of sound.

The character of the bottom apparently affects the strength of a position very little. Certain types of bottom materials may partly absorb the sound and reduce the range of transmission, but the velocity of the reflected wave is probably not changed enough to affect the elapsed times appreciably.

### *6825. Inking Positions on the Boat Sheet*

Each accepted position (see **7635**) should be pricked on the boat sheet and accentuated with colored ink. The position number should be inked nearby for identification (see **7681**). The distance arcs may be inked or left in pencil, as desired. (See also **3251**.)

### *6826. Plotting With R.A.R. Distance Differences*

Ordinarily in R.A.R. the total elapsed time from each of two or more R.A.R. stations is known and is used in plotting a position. However, if returns are received from three or more R.A.R. stations appropriately located with reference to each other, it is possible to plot the position by using the differences between the times to the various stations, provided the velocity of sound is known, the total times themselves being unknown. This is of practical value in R.A.R. where, for example, the record of the bomb explosion is lost for any reason, as where it cannot be distinguished on the chronograph tape because of static. Such returns should not be rejected in an R.A.R survey—they should be recorded in the Bomb Record for plotting at a later date, if time and facilities do not permit their being plotted at the time.

There are several methods by which an R.A.R. position can be plotted graphically, using time differences, the choice depending on the base sheet used or on the number of positions to be plotted. The position can also be found analytically by

computing the distances to the R.A.R. stations and then plotting by conventional methods. The principle involved in the solution of this problem is that the locus of a point which moves so that the difference of distances from two fixed points is a constant, is a hyperbola. The two fixed points are the R.A.R. stations, and the sign of the difference determines the branch of the hyperbola on which the point is found. It follows then that where there are three R.A.R. stations, the R.A.R. position is at the intersection of three hyperbolas, each one of which satisfies the difference conditions for a pair of R.A.R. stations. One of the three hyperbolas merely serves as a check on the position as determined from the other two and will not be considered further. The two hyperbolas giving the best angle of intersection should be the ones used.

The velocity of sound must be known so that the time differences can be converted into meters; otherwise the problem is insoluble. Also, the identity of the two R.A.R. stations to which any given time difference applies and the sign of the difference must be known. If the signs of the two differences were unknown, there would be, theoretically at least, four possible intersections, since each hyperbola has two branches.

It must be borne in mind that a given R.A.R. position is not as strongly fixed by the method of differences as by the conventional methods using total distances. The strength of position in the former case depends on the angle of intersection of the hyperbolas, which angle is always more acute than the angle of intersection of the distance arcs, for any given position.

For the methods explained below, assume three R.A.R. stations, $A$, $B$, and $C$, whose geographic positions are known and which are plotted on a base sheet, and let $P$ denote the unknown position sought. Assume further that the radio returns from the three stations are received in the above order, and let $p$ and $q$ represent the known distance differences, so that $PB-PA=p$, and $PC-PB=q$. Then the three actual distances are $PA=x$, $PB=x+p$, and $PC=x+p+q$, in which $x$ is the unknown constant to be added to the distance differences for plotting by conventional R.A.R. methods. The problem, therefore, is one of determining the unknown distance $x$.

There are several methods of accomplishing this which are described briefly under the following headings:

### A. GRAPHIC METHOD

(*a*) On the base sheet at $B$ scribe a circle with radius $p$ and at $C$ another circle with radius $(p + q)$. The problem is to find a point $P$ which is equidistant from A and the circles with radii $p$ and $(p + q)$. Make a transparent overlay on which is drawn a series of concentric circles large enough to satisfy the conditions. The transparency should resemble the Odessey R.A.R. protractor (**4537**), and adjacent circles should be close enough to each other to permit accurate interpolation by eye. The transparency need have no scale. Lay the transparency over the base sheet and move it around until a circle with radius $x$ is found which passes through $A$ and is tangent to the circles scribed at $B$ and $C$. The desired point P is then at the center of the series of concentric circles on the overlay.

(*b*) In this method a series of concentric circles similar to the Odessey R.A.R. protractor must be drawn on the base sheet with each R.A.R. station as a center. These circles must be constructed so that circles of equal radii are easily identifiable. On a transparent overlay draw two concentric circles, with radii $p$ and $(p + q)$. Lay the transparency over the base sheet and move it around until their common center and the two circles are at equal distances from the R.A.R. stations at $A$, $B$, and $C$, respectively; that is, until the center of the transparency is on a circle from $A$ with radius $x$, the $p$ circle is tangent to a circle from $B$ with radius $x$, and the $(p + q)$ circle is tangent to a circle from $C$ with radius $x$. When the above conditions are satisfied the center of the overlay is at the desired point $P$. Plotters will find this procedure awkward at first as they are not accustomed to this

form of plotting. This method is not practicable in R.A.R. surveys because the three series of closely spaced concentric circles would obscure soundings, positions, and other data on the sheet.

### B. GRAPHIC-APPROXIMATE METHOD

In this method the assumption is made that the hyperbolic lines of position in the vicinity of $P$ are straight lines within graphic limits, which is usually the case where $P$ is not close to any of the R.A.R. stations. There are three variations of this method, the first two of which are modifications of (*b*) above, and which can be used on an R.A.R. sheet with conventional distance circles spaced about 4 inches apart.

(*c*) Select that R.A.R. distance circle from station $A$ on the base sheet, which is as close to position $P$ as can be estimated, and call its radius $x'$. Prepare a transparent overlay as described in (*b*) above and place it on the base sheet so that its center is on the selected distance circle from $A$ and at the same time the $p$ circle is tangent to the distance circle of $x'$ radius from $B$. Then the center of the transparency is one point on the hyperbolic line of position referred to $A$ and $B$. Now unless this happens to be the desired point $P$, the $(p+q)$ circle will miss tangency with the $C$ distance circle of $x'$ radius by a distance which must be accurately scaled and given its correct sign, depending on whether the $(p+q)$ circle falls toward or away from $C$ with reference to the $C$ distance circle of $x'$ radius. Mark the center of the transparency on the base sheet $P'$. Now select another $A$ distance circle with radius $x''$ on the base sheet, which will make the $(p+q)$ circle fall in the opposite direction from $C$, and again place the transparency so that its center is on the second $A$ distance circle and its $p$ circle is tangent to the $B$ distance circle of $x''$ radius. This center is another point on the hyperbolic line of position referred to $A$ and $B$. Mark this center $P''$ and again accurately scale the distance the $(p+q)$ circle misses tangency with the $C$ distance circle of $x''$ radius. The two scaled distances must be opposite in sign, but $P'$ and $P''$ should be as close to each other as practicable. Then connect $P'$ and $P''$ with a straight line which is a chord of the hyperbolic line of position and find point $P$ on it by the proportion $PP' : PP'' ::$ first scaled distance : second scaled distance.

(*d*) As in (*c*) above, plot two points, $P'$ and $P''$, and connect them with a straight line which is a chord of the hyperbolic line of position with reference to stations $A$ and $B$. Then with another transparent overlay on which a circle with radius $q$ is scribed, similarly find points $Q'$ and $Q''$ with reference to stations $B$ and $C$, and connect $Q'$ and $Q''$ with a straight line which is a chord of the other hyperbolic line of position with reference to stations $B$ and $C$. The intersection of the two chords is the desired point $P$ if the conditions have been selected so they intersect; if not, other points must be plotted until two pairs of points have been found which give intersecting lines, with each pair of points as close together as practicable.

(*e*) This method may be found especially useful on the boat sheet. Knowing the approximate position of $P$, set off on a beam compass a distance $x'$, slightly less than $PA$, and with $A$ as a center, scribe a small arc through $P'$; then with a distance $(x'+p)$ set on the beam compass and with $B$ as a center, scribe a second arc intersecting the first arc at $P'$—this is one point on the hyperbola with reference to stations $A$ and $B$. Repeat the above operation with another distance $x''$, slightly longer than $PA$. The point $P''$ thus found is a second point on the hyperbola, and the straight line joining points $P'$ and $P''$ is a chord of the hyperbola. Repeat the operation with reference to stations $B$ and $C$ and obtain a chord of the second hyperbola; the intersection of the two chords is the desired point $P$.

### C. MECHANOGRAPHIC METHOD

In this method a special three-arm device is used. Three metal arms are pivoted at a center, with one edge of each arm serving as a graduated scale from the pivot. The graduations may be on an arbitrary scale, but so marked that equal distances from the pivot can be easily identified on the three arms. Each arm is broken near the pivot and a supplemental adjustable metal strip attached, in such a manner that each arm can be extended by an accurate amount. These supplemental metal strips must be graduated in terms of the base sheet upon which the instrument is to be used.

In plotting a position the scale of the supplemental metal strip on arm $A$ is set at zero, that on arm $B$ at the difference of distance $p$, and that on arm $C$ at the difference of distance $(p+q)$. It is apparent that any graduation $x$ on the three arms is at $x$ distance from the pivot on the $A$ arm, at $(x+p)$ distance on the $B$ arm, and at $(x+p+q)$ distance on the $C$ arm. The device is then manipulated until the readings on the arms at stations $A$, $B$, and $C$ are equal; the center of the device is then

at the desired point $P$. The manipulation of the device is facilitated if vertical pins are set at the positions of the R.A.R. stations $A$, $B$, and $C$, for the arms to be held against.

#### D. ANALYTICAL METHOD

In this method the R.A.R. position is found by computing the total distance between station $A$ and the desired point $P$, and plotting by conventional methods. The following formulas express the necessary relations between the given data for the solution of the problem, in which $a$=distance between $B$ and $C$; $b$=distance between $A$ and $C$; and $c$=distance between $A$ and $B$.

$$x=\frac{c^2-p^2}{2(p+c\cos\theta)}=\frac{b^2-(p+q)^2}{2[p+q+b\cos(A-\theta]} \tag{1}$$

where $A$ is the angle $PAB$, and $\theta$ is the angle measured from $AB$ toward $AC$ in such a direction that the direction of $AP$ is reached before $AC$ is reached.

$$q+p(1-m)=(mc-b\cos A)\cos\theta-b\sin A\sin\theta \tag{2}$$

$$\text{where } m \text{ is } \frac{b^2-(p+q)^2}{c^2-p^2}. \quad \text{Note that } m \text{ is always positive.} \tag{3}$$

$$\text{Now let } mc-b\cos A=d\cos\delta \tag{4}$$

$$\text{and } b\sin A=d\sin\delta$$

Solve for $d$ and $\delta$. Let $d$ be always positive, then $\delta$ is uniquely determined.

Then,

$$\cos(\theta+\delta)=\frac{q+p(1-m)}{d} \tag{5}$$

Mathematically, there are two solutions for $(\theta+\delta)$ and hence for $\theta$. However, in practice, the approximate angle $\theta$ will usually be known and hence the proper $\theta$ can be determined immediately.

The order of the solution should be as follows: Solve for $m$ in equation (3), for $d$ and $\delta$ from equation (4), for $(\theta+\delta)$ and $\theta$ itself from (5). All values are now known so that $x$ can be computed from equation (1).

Forms for logarithmic and machine computation can be furnished by the Washington Office.

## 683. R.A.R. SOUNDING LINES

In hydrography it is desirable to sound along a regular system of lines to cover an area thoroughly in an efficient and economic manner. In R.A.R. surveys, especially where strong currents prevail, it is frequently difficult to follow proposed lines, principally because of the time that elapses after each position before it is plotted. Depending on the reliability of the data and the expertness and diligence of the chronograph attendant and the plotter, the ship's position is not known until 4 to 6 minutes after the time of the position. The officer-in-charge must always bear this in mind and, where a position plots off the line, the course must be changed more than is apparent from the boat sheet to bring the ship back on line, because of the distance that the ship has traveled since the position.

The change in course needed to bring the ship back on line may be determined from its dead-reckoning position at the instant of change. The new course must be measured relative to the last course made good so as to take account of the leeway. To follow the proposed line, the course should be changed again when the ship is judged to have regained the line, making due allowance for the known leeway.

Carefully calculated courses should rarely need to be changed more than 1° or 2° after each position, although larger changes are sometimes necessary where there are erratic currents. Excessive changes in course, causing the positions to plot alternately on opposite sides of the proposed line, should be avoided.

### *6831. Best Direction of Lines*

The direction of a system of sounding lines is based principally on the bottom relief but it is also selected so as to cover the area in a thorough and economic manner as described in **3141A**. In R.A.R. surveys there is an additional factor to consider, for the system of sounding lines should not parallel the bisectrices between R.A.R. stations if this can be avoided. Positions are comparatively difficult to obtain near a bisectrix and impossible where the sounding line nearly coincides with a bisectrix. (See **6814** and **6823**.) Therefore, insofar as practicable, R.A.R. sounding lines should be planned in a direction more nearly normal to, than parallel to, the bisectrices.

If the project instructions specify, or the bottom relief makes it desirable, that lines be run in a certain direction, the R.A.R. stations should be established where the bisectrices will cross the sounding lines at an angle greater than 45°, if practicable. Most of the difficulties will thus be eliminated.

### *6832. Splits and Development*

On large-scale surveys, where the sounding lines are closely spaced, it is difficult to run *splits* and develop areas closely, using R.A.R. control only. Such lines have to be run much more precisely than those of the general system, and the lapse of time between a position and its plotting makes this difficult.

Where a split has to be run between two closely spaced lines, a preliminary run of sufficient length should be made to permit taking and plotting a trial position before the line is reached. Best results are obtained if the preliminary run is made in the same direction as the azimuth of the split, but it can be made at any angle with the line if proper allowance is made for the turning radius of the ship when turning onto the course. The course should be changed long enough before reaching the line so that the ship will be on the correct heading when on line.

Development lines are usually run normal to the direction of the general system of lines, or at some angle for the best development of the feature. Generally such lines must be closely spaced. Each line should be fixed by at least two R.A.R. positions, and to provide for this it is occasionally necessary to run longer lines than would be required just to cover the feature. For best control of a development line an R.A.R. position should be obtained immediately after the ship is on the desired course. The last position on a line, just before a change in course is made, may be plotted by dead reckoning.

## 684. Bombing Operations

The final stage in bomb preparation, the ignition, and throwing the bomb overboard, are operations which collectively are known as *bombing* in R.A.R. The final step in preparing the bomb is made after a signal has been received from the chronograph attendant or the bridge. At receipt of a second signal the bomb is ignited and thrown overboard. After the personnel of a vessel have been engaged in R.A.R. for some time, the procedure of bombing becomes routine and experienced personnel are able to perform their duties and obtain the data with a minimum of delay.

The most important operation in bombing is the final preparation of the bomb, as the detonator is inserted into the explosives in the bomb at this time. This operation must be performed with the greatest care and attention, as it is the most dangerous required in the handling of the explosives on board ship.

### *6841. The Bombing Station*

The bombing station is the deck space on board ship where the final step of bomb preparation takes place, and where the bombs are ignited and thrown overboard. It should be located near the stern of the vessel and the position from which bombs are thrown overboard must be near the rail and unobstructed by rigging.

The important feature of the bombing station is the bomb locker in which the bombs are stowed. This is constructed to be used as a workbench by the bomber in the final preparation of the bombs. It should contain several metal-lined drawers of various depths to accommodate bombs of various sizes. Metal from which sparks can be struck must not be used in the construction. The top of the locker should be constructed as a workbench with four sides to prevent bombs from rolling off, and the bottom and sides of the recessed bench should be cushioned with a layer of heavy felt or other padding material. It should be fitted with a hinged cover which may be raised and secured in an upright position. A small padded compartment should be provided in which to stow the detonators needed for immediate use.

The heating element of an electric stove is a convenient and safe means for lighting bomb fuses. Two types are manufactured: one is an open type, the wire coil being exposed; but in the other, known as a calrod element, the wire coil is enclosed in a protective metal tube. The latter type is preferable, for the heating element is protected from spray and it does not burn out readily, but it requires a little more time to reach the required heat for lighting the fuse. The heating element should be protected in a metal container, and located in a protected place near the rail where the bombs are thrown overboard.

The bombing station should be isolated from the rest of the ship as far as practicable. When R.A.R. is in progress and bombs are being fired, warning notices, "no smoking" signs, or red flags should be displayed just forward of the station in all passageways leading aft. No one must be allowed to smoke in the vicinity of the bombing station and the bomber on watch must be instructed to see that this regulation is enforced.

### *6842. Final Preparation of Bombs*

The final step in preparing a bomb is carried out just before it is to be ignited and thrown overboard, between the first signal for a bomb and the final signal to light it (see **6741**).

A number of fuses of various lengths, with detonators attached, are prepared in advance for immediate use. The desired length of fuse is cut from the coil, preferably with a pair of fuse clippers. It is important to cut the fuse square across and insert it into the detonator soon after being cut. The fuse is inserted into the detonator and seated firmly against the explosive, but without any twisting motion. If the fuse is twisted while in contact with the explosive, friction might cause detonation. A crimping tool that makes a watertight crimp should be used to attach the detonator to the fuse. Such tools are designed so they will not pinch the fuse and interfere with its burning. The detonator should be crimped about one-eighth inch from the open end, and after the first crimp it should be rotated about one-quarter turn and crimped again in the same place. The detonator should never be crimped in two places, one above the other, in an attempt to make a watertight seal, for the lower crimp might be too close to the explosive material.

As soon as the signal for a bomb has been received, the bomber takes a bomb of the size ordered and places it on the workbench. A slender nonmetallic tool is inserted through the hole in the top of the can, to make a cavity in the TNT with a diameter equal to that of the detonator. The detonator is inserted well within the container so that it is embedded in the TNT. With a blunt nonmetallic tool the burs around the hole in the top of the can are pressed around the fuse, taking care not to puncture the fuse with the sharp edges of the burs. The can does not have to be watertight, but the crimp between the fuse and detonator does have to be watertight.

The final preparation of cast-iron bombs, or bombs in the other types of containers, is similar to the above. The fuse for cast-iron bombs should be inserted in the hole in the stopper. A cavity for the detonator is made in the TNT and the stopper with detonator attached is firmly pressed into place.

### *6843. Fuse Length*

A fuse used in detonating an R.A.R. bomb must be sufficiently long to allow the ship to pass out of danger before the explosion occurs, but should not be so long that the bomb will sink to a depth where a misfire is likely. Furthermore, it is desirable to keep the fuse interval as short as practicable, consistent with safety, for the sake of accuracy (see **6853**(*d*)).

Varying lengths of fuse are generally required for bombs of different sizes, for best results seem to be obtained when the bombs explode at about the same depth as the hydrophone of the receiving unit, which is approximately 7 fathoms for sono-radio buoys. To accomplish this, the rate of sinking of different types of bombs should be determined by experiment (see **6846**) and a sufficient length of fuse should be used to explode each type of bomb at the desired depth.

*a. Fuse interval.*—The fuse interval is the interval between the time the bomb is thrown overboard and the time it explodes. It is necessary to know this interval to the nearest second in order to compute the *ship's run* correction (see **6853**(*d*)). For this purpose the time of the bomb explosion can be assumed coincident with its receipt on the chronograph. The fuse interval is timed by means of a stop watch or from the second hand of a clock, except with the Dorsey chronograph where it is recorded on the tape (see **6813**). The chronograph attendant records the interval in the Bomb Record.

### *6844. Igniting Bombs*

With the prepared bomb in hand, the bomber stands by the electric heating element ready to light the bomb. The outer covering at the end of the fuse which is to be ignited should be pressed back slightly to expose the powder train. At the signal to light the bomb, the fuse is held against the electric heater until ignited. This is evidenced by a tongue of flame and spitting sparks about 2 inches long that shoot out of the end the instant the fuse is lighted. This continues for about a second and is followed by smoke rising from the end of the fuse. The presence of smoke indicates that the fuse is burning internally.

Other methods of lighting fuses may be used which dispense with the electric heating element. Two accessories are manufactured for this purpose. One is known as a "pull wire fuse lighter," designed for use during rainy weather; it fits over the end of the fuse and lights the fuse when a wire is pulled. The other, known as a "safety fuse match lighter," seems better adapted for use in R.A.R. It is a short paper tube that can be slipped over the end of the fuse. One end of the tube is coated with the igniting

material used on the heads of safety matches; it is placed in contact with the end of the fuse. The fuse is lighted by simply striking the end of the tube with the edge of a safety match box.

A bomb should be thrown overboard when the flame has progressed about 2 inches into the fuse. It will then rarely be extinguished by the water. To eliminate any possibility of holding the bomb too long after the fuse has been lighted, some bombers press the fuse lightly between the thumb and forefinger to follow the progress of the flame by its heat as it burns internally.

### *6845. Throwing Bombs Overboard*

After the bomb fuse has been ignited, the bomb is held for a few seconds until nothing but smoke is issuing from the end of the fuse. This indicates that the fuse is burning internally and will not be extinguished when submerged. **The bomb must be thrown overboard within 5 seconds after ignition of the fuse regardless of external or internal evidence.** The bomb should be thrown overboard in such a manner that it is upright when it strikes the surface of the water, in order not to dislodge the detonator—this is especially important in the case of cast-iron containers. This is done by holding the bomb with the fuse up and giving it a slight rotary motion as it leaves the hand.

Bombs must be thrown outboard 10 or 15 feet beyond the ship's side so that there will be no danger of their being carried into the propeller by suction.

To ensure a secure footing when handling bombs on a wet deck, suitable matting or safety treads should be used on the deck at the bombing station.

### *6846. Depth of Detonation*

The rates at which bombs of various kinds and sizes will sink may be determined by experiment. For a tin can bomb, use a lid with no hole in it, and for a cast-iron bomb, plug the fuse hole with beeswax. Do not use a bomb with a detonator in it. Lash light twine, such as sail twine, to bombs of various sizes and determine the rate of sinking by measuring the amount of twine payed out in a given number of seconds, timed with a stop watch. The twine must be coiled on deck so that it will pay out freely and not retard the rate of sinking.

When surveying in shoal water, or at other times, it may be desirable to reduce the depth of detonation. A bomb may be prevented from sinking beyond a predetermined depth by suspending it from an inflated paper bag used as a buoy, by a length of twine equal to the desired depth of detonation. Any paper bag of sufficient size to support the weight of the bomb in water may be used. Pieces of wood or other similar articles must not be used for floats, because of the hazard left in case the bomb fails to explode. The paper bags are safe for they will soon become watersoaked and let the unexploded bomb sink to the bottom. The string should be light so that it will break if it fouls anything.

### *6847. Bombing at Buoy Stations*

A buoy is often located with reference to other buoys by R.A.R. distances. Where this method of location is used, bombs must be exploded at one of the buoy stations. The same types of bombs are used, but they must be thrown overboard at the buoy when it is near enough to the bombing station, and more precise timing is required on the part of the bomber. As explained in **2533**, there are two general methods for locating a station in this manner.

If the distances involved are short and only detonators or very small bombs are required, they may be thrown overboard at the buoy from the ship lying-to near the buoy. In such case bombs are ignited and thrown overboard by the bomber at the regular signal from the chronograph attendant, who has the desired number fired in rapid succession, one after the other, without scaling the chronograph tapes until later. The bomber throws the bombs so that they hit the water within a few feet of the buoy, taking care not to hit the buoy structure and damage the bomb.

Where larger bombs are required, the ship must be underway. The ship follows a figure-of-eight course, passing and repassing the buoy, and a bomb is exploded near the buoy each time the bombing station comes abeam of it. The bomber must watch the buoy as the ship approaches it and judge the distance so as to light the bomb just enough in advance so that it will be ready to throw overboard when the buoy structure is abeam. The ship should be maneuvered so that the bombing station will be within approximately 50 feet of the buoy, when abeam. If the bomber judges that the buoy will be beyond a reasonable throwing distance, when it is abeam, he should not light the bomb at all.

#### *6848. Failure to Detonate*

Bombs seldom fail to detonate if they are properly prepared and handled. Any of the following things may occasionally cause misfires:

(*a*) Breaking the fuse in handling it or using fuse that has been crushed or walked on.
(*b*) Wet fuse ends.
(*c*) Cutting the fuse with a dull instrument or cutting it on a slant.
(*d*) Fuse fitted improperly, as when the fuse is not seated closely against the explosive in the detonator, or when the detonator is not properly crimped around the fuse.
(*e*) Loss of powder from the fuse end before it is inserted into the detonator.
(*f*) Too long a fuse, the bomb sinking too deep.
(*g*) Use of too light a detonator.
(*h*) Fuse and detonator dislodged from bomb container.
(*i*) Throwing bomb overboard before the fuse is burning properly.

### 685. CHRONOGRAPH TAPES

The chronograph tape is the original record from which the time intervals to the several R.A.R. stations are determined for recording in the Bomb Record. As the chronograph tape is drawn through the chronograph it passes under two styluses that, correctly adjusted, draw coincident lines near the middle of the tape. (See **673**.) The timing stylus, when actuated, makes short offsets below the line at regular intervals, and the signal stylus, when actuated by a bomb or radio signal, makes a longer offset above the line. From these offset marks on the chronograph tape, the time intervals to each station may be determined.

#### *6851. Reception of Bomb Returns*

After a bomb has been thrown into the water and the chronograph has been started, the chronograph attendant, seated at the chronograph where the tape emerges, holds the *hydro-radio* switch in the position to receive the bomb signal through the hydrophone in the hull of the ship. When the offset caused by the bomb explosion is made on a Gaertner chronograph tape, it is marked by pencil for identification—on a Dorsey chronograph tape it is identified by the zero printed with the next tenth second offset. The switch is then released, or otherwise placed in the position, to receive the radio signals from the R.A.R. stations.

The next offset recorded by the signal stylus under normal conditions will be caused by a radio dash transmitted by an R.A.R. station at the instant the sound wave reaches its hydrophone. This radio signal may be heard through a loud speaker or indicated by the needle of a milliammeter (see **6724**). As each radio return is recorded on the tape, it should be identified by a pencil mark. After the radio return from the most distant R.A.R. station has been recorded, the chronograph is stopped and that part of the tape with the record is torn off. Figure 141 illustrates an R.A.R. record on a tape from a Gaertner chronograph, with the tape broken into four parts for convenience in illustration, and the correct method of marking the returns.

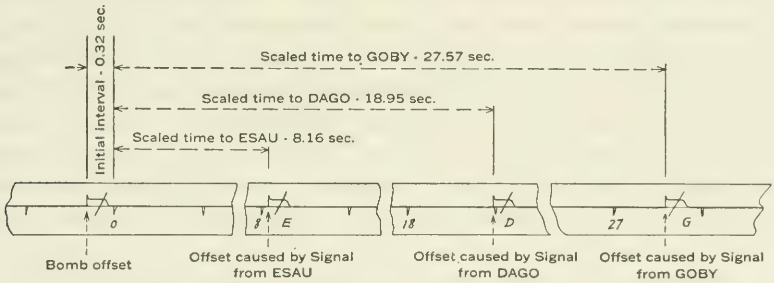


FIGURE 141.—Elapsed times obtained from a chronograph tape.

During heavy atmospheric static it is often difficult, and occasionally impossible, to record radio returns on the chronograph tape. A heavy crash of static will cause a prolonged offset of the signal stylus and a radio signal transmitted during this time will be lost *under* the static. The duration of an offset caused by static may sometimes be reduced by pushing the stylus gently toward the center of the tape, provided the static is not too heavy.

The ship's whistle must not be blown while bomb returns are being received. The whistle not only prevents the radio returns from being heard but also causes a prolonged offset of the signal stylus, a phenomenon which is called "whistle static."

### *6852. Identification of Bomb Returns*

When R.A.R. was first used, the shore station equipment included an automatic key that transmitted a series of radio dashes, when activated by the bomb signal. A different setting of the key at each R.A.R. station varied the length of, and the interval between, the radio dashes, thereby furnishing a positive means of identification on the chronograph tape. However, the series of radio dashes interfered with the reception of returns in close succession and the use of the automatic key was abandoned. Other means must be used by the chronograph attendant to identify the returns from the various R.A.R. stations.

The best clue to the identification of radio returns is the tone of the transmitted signal as heard through the loud speaker. When the radio receiver is properly tuned, the return from each station usually has a characteristic tone which is caused by a slight difference in the crystal frequency of the R.A.R. station, resulting in a small difference in the audible beat frequency on reception (see **6433**). The radio technician and the chronograph attendant soon learn to recognize the different tones and are thus able to identify the stations.

The chronograph attendant should always know the sequence in which the radio returns should come. For the first position in a new locality the officer-in-charge

should give this information. The length of the signal offset may occasionally be used as a means of identification. The duration of a signal depends principally on the strength of the bomb signal at the R.A.R. station, which is variable with distance, and on the sensitivity of the R.A.R. station, and to a lesser degree on the strength of the batteries. If one of the stations is more sensitive than the others, it will transmit a longer signal which will be recorded on the chronograph tape as a longer offset and furnish a means of positive identification.

In routine operations, after a few positions, the identification of the various stations is simple when the positions are obtained at equal time intervals and the ship is maintained on approximately the same course. The chronograph attendant can take the differences between successive time intervals from an R.A.R. station and from these determine whether the time intervals are increasing or decreasing and the magnitude of the change. By extrapolation he can closely estimate the time interval for a station at the next position, and he may often be able to identify the first of two returns where the position is near a bisectrix between two stations (see **6823**). The officer-in-charge should also notify the chronograph attendant when a major change in course is made and about how this will affect the differences between successive time intervals.

In rough weather a sono-radio buoy that is too sensitive will transmit radio signals as the buoy structure rises and falls with the swell or waves; or the noise from the propeller of a nearby vessel may cause an R.A.R. station to transmit signals at various intervals. Such signals are called *strays* and the sounds received are short and sharp, resembling somewhat the chirping of small birds or crickets. Because of their shortness, such signals are usually easy to distinguish from the bomb returns but, when such a stray is recorded just before the bomb return, too close to be distinguished by ear or recorded as a separate offset on the chronograph tape, an error may result in the measured time interval. During periods when strays are being transmitted by any station, the chronograph attendant must pay particular attention to the returns from that station, and any which he suspects of stray interference should be questioned in the Record, and the plotting station should be warned when the time intervals are communicated.

After the returns have been identified, the identity of each should be indicated on the chronograph tape. The name of the station may be written in full or it may be merely indicated by using the first letter of the station name, as in figure 141.

### *6853. Scaling Chronograph Tapes*

A complete record on a chronograph tape contains a series of signal offsets on one side of the centerline, which have been identified by pencil marks when received, and time offsets at regular intervals for its entire length on the opposite side of the centerline.

To measure the time intervals it is only necessary to determine, in fractions of a second, where each signal offset occurs between two adjacent time offsets, first counting the time offsets. The time offsets on the tape should be numbered, unless this is done automatically as on the Dorsey chronograph (**6733**), using as an initial the first time offset after the bomb explosion. This initial is numbered zero and, counting from this offset, each fifth one is numbered, as well as the offset preceding each radio return (see fig. 141). To aid in numbering the time offsets on a Gaertner chronograph tape, a length of tape with seconds marked on it may be run off, and the offsets numbered consecutively for use as a standard scale. This standard tape may be secured to the

top of the chronograph desk or table where it will be convenient for the chronograph attendant to compare any other tape with it when numbering the time offsets.

An R.A.R. chronograph scale (**4825**) is used to measure fractions of a second on a Gaertner chronograph tape. With the horizontal lines of the scale parallel to the centerline on the tape, the scale is adjusted until the extreme converging lines on each side of the scale coincide with the time offsets where they leave the centerline. Where the signal offset leaves the centerline of the chronograph tape, the fractional part of the second may be read directly in tenths and estimated to hundredths. For a Dorsey chronograph (**6733**) no scale is necessary because the time offsets are registered every tenth second on the tape.

In connection with the determination of time intervals from a chronograph tape the following terminology is used:

(*a*) The *initial* is the first time offset after the signal offset caused by the bomb explosion. It is marked zero on the chronograph tape and all time intervals are reckoned from it.

(*b*) The *initial interval* is the interval between the bomb signal offset and the initial or zero. It is always measured to the left from the initial, so that this interval may be applied as a plus correction to the measured times of the radio returns (see (*c*) below). Errors are occasionally made by measuring the initial interval to the right from the time offset *preceding* the bomb explosion.

(*c*) The *scaled time* is the interval between the initial and the signal offset indicating the receipt of the sound at the R.A.R. station. It is always measured from the initial, from left to right. It is equal to the fractional part of a second, measured from the time offset preceding the return, added to the total number of seconds from the initial. Scaled times are illustrated in figure 141.

(*d*) *Ship's run correction.*—The position that is determined is the position where the bomb strikes the water (**6811**), but by the time of the explosion, the ship, if underway, will be some distance from this position and a measurable time will be required for the sound of the explosion to reach the ship's hydrophone. The actual time of the explosion is always earlier than is indicated on the chronograph tape. All tape times must, therefore, be corrected by an interval based on the speed of the ship, the fuse interval (see **6843***a*), the distance between the bombing station and the position of the ship's hydrophone, the depth of the ship's hydrophone, the depth of detonation, and the velocity of sound in sea water.

A table for various fuse intervals and ship speeds is convenient for obtaining the ship's run correction. This table should be prepared in advance and posted at the chronograph station. It can be computed from the formula:

$$T=\frac{\sqrt{(b-h)^2+d^2}}{v}$$

in which $T$=ship's run correction in seconds; $b$=depth of bomb explosion in meters; $h$=depth of ship's hydrophone in meters; $d$=distance in meters the ship (hydrophone location) has traveled during the fuse interval; and $v$=velocity of sound in meters per second. It is sufficiently accurate to base the table on an average rate of sinking, regardless of bomb size, and on an average surface velocity of sound expected during the period, so that the same table of corrections may be used throughout a season.

The ship's run corrections given in table 22 were computed by using a uniform rate of bomb sinking of ½ fathom per second, a depth of the ship's hydrophone of 2 fathoms,

and a velocity of sound of 1,490 meters per second, for the special case where the bombing station is directly over the ship's hydrophone.

TABLE 22.—*Ship's run corrections*

[In seconds]

| Fuse interval, seconds | *Speed in knots* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 7 | 0. 01 | 0. 01 | 0. 01 | 0. 02 | 0. 02 | 0. 02 | 0. 02 | 0. 03 | 0. 03 | 0. 03 | 0. 03 |
| 8 | . 01 | . 01 | . 02 | . 02 | . 02 | . 03 | . 03 | . 03 | . 03 | . 04 | . 04 |
| 9 | . 01 | . 02 | . 02 | . 02 | . 03 | . 03 | . 03 | . 03 | . 04 | . 04 | . 04 |
| 10 | . 01 | . 02 | . 02 | . 02 | . 03 | . 03 | . 03 | . 04 | . 04 | . 05 | . 05 |
| 11 | . 02 | . 02 | . 02 | . 03 | . 03 | . 03 | . 04 | . 04 | . 05 | . 05 | . 05 |
| 12 | . 02 | . 02 | . 03 | . 03 | . 03 | . 04 | . 04 | . 05 | . 05 | . 05 | . 06 |
| 13 | . 02 | . 02 | . 03 | . 03 | . 04 | . 04 | . 05 | . 05 | . 05 | . 06 | . 06 |
| 14 | . 02 | . 02 | . 03 | . 03 | . 04 | . 04 | . 05 | . 05 | . 06 | . 06 | . 07 |
| 15 | . 02 | . 03 | . 03 | . 04 | . 04 | . 05 | . 05 | . 06 | . 06 | . 07 | . 07 |
| 16 | . 02 | . 03 | . 03 | . 04 | . 04 | . 05 | . 06 | . 06 | . 07 | . 07 | . 08 |
| 17 | . 02 | . 03 | . 04 | . 04 | . 05 | . 05 | . 06 | . 06 | . 07 | . 08 | . 08 |
| 18 | . 03 | . 03 | . 04 | . 04 | . 05 | . 06 | . 06 | . 07 | . 08 | . 08 | . 09 |
| 19 | . 03 | . 03 | . 04 | . 05 | . 05 | . 06 | . 07 | . 07 | . 08 | . 09 | . 09 |

Table 22 may be used as a basis for computing the corrections for any ship by adding (or subtracting) the time interval equivalent to the distance between the bombing station and the ship's hydrophone to those given in the table, provided this distance is not too great, and provided further that the average surface velocity of the area does not differ by more than 20 meters per second from that used to compute the table.

The ship's run correction must not be used to correct time intervals obtained while the ship is lying-to, bombing at buoys. A correction based on the average distance from the buoy to the ship's hydrophone, the depth of detonation, and the velocity of sound, must be computed and used to reduce the scaled times.

(*e*) The *elapsed time* is the total time interval from the bomb explosion to the arrival of the sound at the R.A.R. station. It is the scaled time plus the initial interval plus the ship's run correction.

The method of recording time intervals in the Bomb Record is described in **8311**.

### *6854. Disposition of Chronograph Tapes*

Immediately after the time intervals from a chronograph tape have been communicated to the plotting station, the values should be verified, if there is sufficient time between positions, or if someone can be assigned to the chronograph station for this purpose. The radio technician on watch may occasionally be able to do this when he is not otherwise engaged. If the time intervals are not verified at this time, this must be done later. The chronograph tapes must be marked for future identification and folded and filed in a manner for easy reference.

Chronograph tapes are marked for identification with rubber Stamp No. 41, shown in figure 142, which provides spaces in which the position number, the day letter, the sheet number, and the date should be entered. The stamp is used on the

back of the tape near the initial end, and the data should be entered before the tape is folded.

After the tapes have been verified they are folded to a uniform size. A Wright bobbin, similar to the instruments used by net makers to obtain a uniform mesh, may be made from a thin piece of hardwood or plastic material on which the tapes may

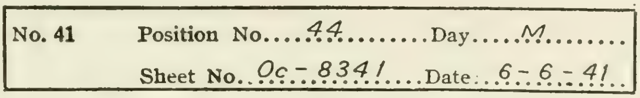
No. 41 Position No.....44.........Day.....M........
Sheet No..Oc.-.834/.....Date:..6-6-41..

FIGURE 142.—Facsimile of stamp used on chronograph tapes.

be uniformly folded. The Wright bobbin should be about 5 inches long and the end edges should be beveled slightly so that the folded tape may be removed without difficulty. The tape should be folded with the initial end on the outside so that the identifying data will be exposed to view.

The folded chronograph tapes should be filed in numerical order in a box or a drawer at the chronograph station and, at the end of survey operations each day, they should be tied in a package, marked so that it may be identified. Strips of stiff cardboard, of the same size as the folded tapes, should be placed on the top and bottom of the package and the whole held together by rubber bands near each end. The two cardboard strips may be stamped with rubber Stamp No. 41 and the identifying data entered.

The packages of chronograph tapes should be stored in the field records locker and be preserved with the same care as any original records.

The tapes must be preserved for the use of the smooth-sheet plotter and accompany the other survey records until the smooth sheet has been plotted and is ready to be sent to the Washington Office, when they may be destroyed.

# CHAPTER 7. THE SMOOTH SHEET

The *smooth sheet* is the name given to the hydrographic survey when reduced to plot form. It is essentially a record of the soundings taken during the field survey, but contains other data necessary for a proper interpretation of the survey, such as depth curves, bottom characteristics, names of geographic features, and control stations. The smooth sheet is plotted with the utmost care in the drafting room of the ship or a field office either as the survey progresses or after it is completed. After registry, verification, and review in the Washington Office (see **93**), the smooth sheet becomes the official permanent record of that particular survey. It is as complete for the water area as it is practicable to make it, and subsequent reference to the original Sounding Records is rarely necessary.

## 71. THE SHEET

### 711. Smooth-Sheet Paper

It is obvious that surveys which cost thousands of dollars to execute should be plotted in their final permanent form on the best practicable medium available. Experience has shown this to be first-quality white drawing paper mounted on muslin. This paper is known as *smooth-sheet paper*, and is available in several makes and sizes. Smooth sheets shall be prepared only on paper furnished by the Washington Office for that purpose.

#### *7111. Whatman's Paper*

The standard paper for smooth sheets is Whatman's paper, available in only one size, 31 by 53 inches. In this paper the muslin backing extends approximately 1 inch beyond the paper on each edge, which feature tends to preserve the edges of the paper during extensive use and also prevents cracking. Whatman's paper shall be used for all smooth sheets where the size permits, and this requirement must be given full consideration in planning the sheet layout for any given area (see **1361**).

#### *7112. Other Papers*

Other mounted smooth-sheet paper is available in widths of 36 and 42 inches, in continuous rolls of 10 yards each. This should be used when the layout of sheets requires the use of larger sizes than the standard, as is frequently the case with offshore surveys. The quality of the different makes varies, "Paragon" being considered the finest drawing paper made. But this is foreign made and is difficult to get at the present time. In 1942 the best available paper is Keuffel & Esser No. 13320 *DM*.

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When paper other than Whatman's standard is used, the smooth sheet shall have noted in the margin the maker's name and the trade name or number of the particular paper, if these are known. Some papers have this information imprinted at regular intervals along the margin but if this imprint does not contain all the desired data or if the entire imprint does not appear on the smooth sheet, it must be noted thereon in ink.

### *7113. Defective Paper*

Drawing paper is purchased by the Federal Government in accordance with standard specifications. These require generally that paper be free of surface imperfections, that it be subject to a minimum dimensional change, that it permit inked lines to be drawn without spreading or *feathering,* and that it permit several successive erasures, with rubber or steel, in the same spot, on which lines can be subsequently inked with little or no spreading or feathering. In addition, the paper must not be so stiff and rigid that it will not withstand a reasonable amount of rolling and flexing without cracking.

Notwithstanding the specification requirements, considerable variation in the quality of smooth-sheet paper is found in practice. Paper which does not comply to a reasonable degree with the above general requirements shall not be used for smooth sheets and the Washington Office shall be notified of the specific fault in a letter stating the maker's name, the trade name of the paper, and the date of shipment to the party, if these are known.

### *7114. Paper Distortion*

Drawing paper, not mounted on metal, does not exist which is free of distortion under varying conditions of temperature and humidity. This distortion is a decided nuisance to the surveyor in his field work and to the cartographer who subsequently uses the smooth sheet in the Office. The distortion is more troublesome in rainy climates and in localities where there are rapid and large changes in humidity. Because of this distortion, distances once laid off cannot be assumed to retain their correct length. If distances are plotted for use at some future date, it is necessary to verify them before use.

The best quality of smooth-sheet paper is manufactured so that the percentage of contraction or expansion is nearly equal in all directions. Such distortion can be compensated for, especially if it occurs after the survey has been completely plotted, because the effect is merely a change in scale. Where the percentage distortion is not uniform in all directions, as is the case with many grades of paper, its effect is *relatively* easy to compensate for, *provided* certain precautions are taken in laying out projections (see **1362**).

One test for distortion made in the field in Alaska in 1931 showed a maximum dimensional change in a standard Whatman sheet of 1.12 percent in length and 0.62 percent in width; the sheet assuming its greatest dimensions on a foggy day when the sheet was damp and its minimum on a clear day when the sheet was quite dry.

Recent tests in the Washington Office show that the following distortions may be expected for the various papers listed:

TABLE 23.—*Paper distortion*

| Type of paper or material | Percentage of distortion caused by a change from 27 to 89 percent relative humidity | |
|---|---|---|
| | Across short dimension of sheet or roll | Along long dimension of sheet or roll |
| Cellulose acetate | 0. 29 | 0. 19 |
| Buff paper, K. & E. No. 13322–M | 0. 51 | 0. 25 |
| Chart paper (unmounted) | 0. 65 | 0. 29 |
| Buff paper, K. & E. Duplex No. 141 (in sheets) | 0. 75 | 0. 35 |
| White paper, Weil No. 72 | 0. 61 | 0. 39 |
| Buff paper, K. & E. Duplex No. 141 (in rolls) | 0. 65 | 0. 40 |
| White paper, K. & E. Paragon | 0. 97 | 0. 45 |
| White paper, Whatman | 0. 40 | 0. 56 |
| Tracing paper, K. & E. Ionic No. 197 H | 0. 54 | 0. 13 |
| Tracing paper, Post No. 173 | 0. 82 | 0. 28 |
| Tracing paper, K. & E. Doric | 0. 99 | 0. 27 |
| Tracing cloth, K. & E. No. 13303 | 1. 00 | 0. 28 |

### *7115. Seasoning Drawing Paper*

Smooth-sheet paper should be well *seasoned* in the climate in which it is to be used and for as long a period as practicable before the projection is drawn. Paper in tight rolls, or in stacks or piles, will not season. Each sheet should be laid out or hung up separately where it will be completely exposed to the air on both sides for at least a few days, if not weeks, before use. For best results the period of seasoning should embrace a great variation of temperature and humidity.

If a sheet cannot be seasoned by laying it flat, it should be hung from successive edges and subsequently laid flat for several days before use.

The contraction and expansion seems to be greater during the seasoning period than subsequently. The paper *seasons* and *settles down* so that less distortion may be expected later.

### *7116. Drawing Paper in Rolls*

Drawing paper in rolls is tightly rolled by the manufacturer and soon assumes a *set* in this position. It must be unrolled with extreme care or it will have a tendency to *buckle* or perhaps even crack. It is best to unroll it gradually over a period of several days before trying to put it in a flat position. This is done by first loosening the outer turns of the roll, until as much paper as is likely to be needed at the time has assumed a diameter perhaps twice as large as the roll had originally. The next day it is expanded again in diameter and so on, leaving it in the enlarged roll each time for a day, if possible, until it can be cut off the roll and laid flat for seasoning.

### *7117. Drawing Paper Requisitions*

All smooth-sheet paper requirements should be requested from the Washington Office by ordinary letter, specifying the kind, grade, make, size, and quantity desired.

## 712. SMOOTH-SHEET SIZE

The standard size of smooth sheets is 31 by 53 inches and they shall ordinarily not exceed this size. It is sometimes impracticable to maintain this limit because of

the configuration of the shoreline, the availability of the signals, and the necessity for controlling offshore hydrography from shore signals. But the maximum size, which shall never be exceeded under any circumstances, is 42 by 72 inches.

For projections made in the Washington Office on the projection ruling machine the maximum size of the area on which lines can be ruled and the maximum size of the paper are given in **7327**.

### *7121. Dog-Ears*

*Dog-ears* are small drawing paper extensions to the smooth sheet used for including control stations or portions of sounding lines that plot beyond the limits of the sheet unavoidably or through an error in the original layout.

Dog-ears must be avoided wherever possible. Eventually they almost always tear off or become so mutilated that they must be removed, and the smooth sheet itself is generally *buckled* in the process of adding the extension. Extreme care must be exercised in making the layout in order to ensure that all the needed control will fall within the limits of the sheet.

Where it is necessary to use a permanent dog-ear, the paper shall be neatly *stapled* to the smooth sheet with a wire stapler, using the minimum number that will ensure permanence, and avoiding interference with plotted information. Under no circumstances shall a permanent dog-ear extend more than 6 inches beyond the edge of the sheet.

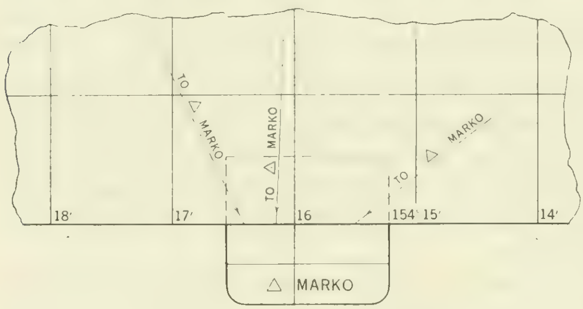



FIGURE 143.—Temporary dog-ear for smooth sheet.

If only a single station is to be included, the dog-ear shall be made of tracing paper, temporarily added to the smooth sheet by rubber cement or in any other way which will not damage the sheet. Three fine inked lines shall be drawn on the smooth sheet toward the station on the dog-ear, of such lengths and azimuths as will permit relocating the station in the future on another temporary dog-ear, should that become necessary. Each such line shall be marked thus: "to △ MARKO" (see fig. 143).

### 713. AUXILIARY PLOTTING SHEETS

Grained or painted aluminum sheets and drawing paper mounted on aluminum sheets are occasionally useful as accessories to the smooth sheet for—

(*a*) Plotting and adjusting the positions of survey buoys located by any of the methods described in section **25**, when plotting is preferable to computation. For example, where the computations are too involved, as in the case of cuts obtained from a vessel whose position is determined by a three-point fix (see **2514** and **2552**); where buoys are located by taut-wire distances; or where they are located by subaqueous sound ranging.

(*b*) Plotting and adjusting hydrographic positions located by; dead reckoning, astronomic sights, R.A.R., and combinations of these.

In all cases in which aluminum sheets are used as intermediaries the final results must be transferred to the smooth sheets; in the case of control, by *dms.* and *dps.* (see **7411**); and in the case of hydrographic positions, either by *dms.* and *dps.* or by a tracing-paper transfer similar to that described in **7413**. As finally plotted, the smooth

sheet must be complete without the necessity of reference to the aluminum sheet which is not a part of the permanent records. The smooth sheet itself, however, *must not* be plotted on aluminum.

### *7131. Grained Aluminum Sheets*

The maximum size of aluminum sheets available at the Washington Office is 38 by 54 inches and they are all 0.02 inch thick. This size or smaller can be furnished either grained, painted, or mounted with drawing paper. A sheet of maximum size costs about $2.50 and the cost of graining is approximately 60 cents per sheet.

The grained surface of an aluminum plate will take either pencil or ink, but the abrasive nature of the surface wears a pencil point down so rapidly that it is difficult, if not impossible, to draw fine lines with a pencil sharpened to a chisel point. Soft pencil marks can be removed with art gum. A hard eraser should not be used since it removes the grain and once this has occurred neither ink nor pencil marks can be made on that portion, unless it is subsequently roughened with a snake slip. Ink can be removed from the grained surface by the use of water or a dilute solution of oxalic acid (1 ounce oxalic acid crystals to 15 ounces of water). A slight stain will remain which can be removed by the use of a snake slip.

Used aluminum plates need not be returned to the Washington Office.

### *7132. Painted Aluminum Sheets*

Painted aluminum sheets are similar to the above, except that, instead of being grained, the drawing surface is provided by spraying the aluminum with enamel paint. The plates are generally given three or four coats of the enamel, applied in the same manner as is the finish on automobile bodies.

Both ink and pencil work can be done on painted aluminum sheets although with not the same facility as on a good grade of drawing paper.

### *7133. Mounted Aluminum Sheets*

Drawing paper mounted on aluminum sheets is the most satisfactory solution of the distortion problem if the sheets are not unduly exposed to moisture. The paper must be mounted on both sides of the aluminum regardless of whether one or both sides are to be used; otherwise the paper will contract or expand and so warp the aluminum sheet that it will not lie flat. Mounted aluminum sheets are prepared in the Washington Office and any make of unmounted drawing paper can be used. The kinds ordinarily used are chart paper or two-ply Bristol board, depending on the purpose for which they are intended. (See also **233**.)

In mounting, the paper is applied to the two sides, one at a time, with a high quality lithographic paste, sparingly used and avoiding excessive moisture, as the latter has a tendency to make the paper surface porous or *mushy* which ruins the fine drawing quality of the paper. One of the requirements for successful mounting is that the paper must be bonded to the aluminum under considerable pressure, this pressure being more important than the quality of the paste.

Some difficulty has been encountered with the moisture in the paste oxidizing the aluminum and causing blisters to form at some future time. Of course this is no drawback if the sheet is being prepared for immediate temporary use. This difficulty can be overcome in various ways, one of the most successful of which is coating the aluminum with shellac before mounting.

## 714. Tracing Mediums

### *7141. Tracing Cloth*

Tracing cloth is a fine semitransparent linen or cotton cloth, sized on one side, and dull on the other. The best grade is free from pinholes. Because starch is used in its preparation, water will ruin and spot the surface, the spots showing on any reproductions. When working with tracing cloth, the portion not being used should be protected from perspiration by a sheet of paper.

The dull side of the tracing cloth should be used for all work because it takes ink better. Inking on tracing cloth is facilitated by dusting with talc or pounce, rubbing lightly with a cloth to remove traces of grease which prevent the flow of ink from the pen.

Tracing cloth distorts considerably more with age and climatic changes than tracing paper and therefore should not be used where a minimum of distortion is required. The best grade of cloth is not as transparent as a good grade of tracing paper.

The most satisfactory tracing cloth on the market in 1942 is "Micro-Weave," fabricated by Holliston Mills Company. It is made in 10- and 20-yard rolls in almost any width desired, and in rectangular sheets in a number of sizes from 19 by 24 inches to 41 by 59 inches. The sheet form is available on the General Schedule of Supplies, but the roll form is not. An inferior grade of cloth in 24-yard rolls can be furnished from the Schedule in widths of 30, 36, and 42 inches. This grade is suitable for use in protecting the smooth sheet during plotting (see **761**).

### *7142. Tracing Paper*

Tracing paper (or vellum) is a thin tough semitransparent paper suitable for making tracings of drawings, or for miscellaneous use where permanence is not important or where pencil work is sufficient. The best quality is odorless, white, 100 percent rag, with a high degree of transparency and smooth surface, the texture permitting erasures without damage to the paper.

The best tracing paper, not available in 1942 because of the war, is foreign made under the trade name "Doric" and is marketed by Keuffel & Esser Company, New York. It is usually obtained in 20-yard rolls in widths of 30, 36, and 42 inches. Substitutes must be selected with care as there are many inferior grades on the market. Post's No. 173, fabricated by Frederick Post Company, Chicago, Illinois, is satisfactory for all except the most critical work.

### *7143. Cellulose Acetate*

Transparent cellulose acetate sheeting (better known under the more familiar trade name "Celluloid") is useful either as a tracing medium or as a transparent cover for smooth sheets, maps, charts, etc. Cellulose nitrate sheeting must not be used since it is highly flammable and its presence creates a definite fire hazard. Cellulose acetate on the other hand burns at about the same rate that paper does.

The sheeting is used in two grades: (1) low shrinkage grade, for work requiring a minimum of distortion, and (2) ordinary grade, for purposes in which dimensional changes are not important.

The types of cellulose acetate ordinarily available are described below. All four kinds can usually be furnished by the Office although only the first three are on the General Schedule of Supplies.

(*a*) Cellulose acetate sheeting, special low shrinkage, one side frosted for drafting, 40 inches wide by 0.008 inch thick, in sheets 50 and 60 inches long and in rolls.

(*b*) Cellulose acetate sheeting, ordinary grade, one side frosted for drafting, in sheets 20 by 50 inches in size, and in thickness 0.005 inch, 0.0075 inch, and from 0.01 inch to 0.125 inch.

(*c*) Same as (*b*), except both sides are clear.

(*d*) Cellulose acetate sheeting, ordinary grade, clear, available in rolls up to 40 inches wide and from 0.00088 to 0.002 inch thick. Sold under the trade name of "Rigid Kodapak" by Eastman Kodak Company.

The frosted sheeting is preferable for either pencil or ink work. The clear sheeting cannot be used for pencil work and is not too satisfactory for ink work.

To ensure ease in drafting and the most permanent bond of the celluloid ink (see **7261**), the surface of both the frosted and clear sheeting should be cleaned thoroughly with either ammonia (U.S.P.) or magnesium carbonate, applied with a soft cheesecloth. Tracing cloth powder can also be used for this purpose, but magnesium carbonate seems to give better results.

## 72. DRAFTING AND LETTERING

### 721. Character of the Drafting

Artistic drafting and lettering are neither necessary nor desirable on a smooth sheet. A hydrographic survey is an engineering product and the resulting smooth sheet should give the appearance of such, rather than that of a work of art. The final result must be first, accurate; second, legible; and third, neat. While neither expert draftsmanship nor penmanship is required, the drawing should be of such quality that there will be no impression of carelessness, since a drawing apparently carelessly made is likely to reflect on the accuracy and the reliability of the field work. Care and patience combined with sufficient practice will produce the necessary accuracy and legibility.

It is particularly important that the smallest details appear on the smooth sheet accurately and clearly. In general, it should be possible to read, without difficulty, everything on the smooth sheet without the use of a magnifying glass. Those engaged in constructing, inking, and lettering smooth sheets should constantly keep in mind the fact that photographic copies of smooth sheets are frequently made for the use of agencies and persons, who have no access to the original documents, and that often these copies are at a one-half reduced scale.

It is only by following prescribed standards that an entirely satisfactory smooth sheet will be produced (see fig. 171). Particularly important is the use of standard symbols (see figs. 169 and 189), as great confusion often results where nonstandard symbols are used or where symbols are drawn so poorly as to make misinterpretation possible. Soundings, in particular, must always be clear and legible (see fig. 163).

### 722. Orientation of Smooth Sheet

North shall always be considered the top of the smooth sheet, whether or not the projection lines are parallel to the edges of the sheet. In plotting and inking smooth sheets all lettering and numerals of any kind shall be so lettered as to be read from the south (see **7733**). Where geographic names or legends cannot be lettered on an east-west line, but must be lettered at an angle or on a curve, they shall be so arranged as to be read when looking directly north (see **7872**).

## 723. Lettering

The lettering on a smooth sheet should be bold rather than the reverse. Extremely small letters and numerals should be avoided unless lack of space renders a small size absolutely necessary. Thin ink should be avoided. Unless ink of sufficient body is used, the central part of the inked line frequently thins out, particularly where a mechanical lettering set is used. This results in a poor appearance and makes satisfactory photography of the smooth sheet impossible. Each inked line, whether in black or color, should present a solid uniform appearance throughout.

It should be noted that, in general, any number appearing in the water area of the smooth sheet should be in slanting numerals, except of course the soundings and position numbers, which are vertical (see **7825** and **7843**).

Periods shall not be used in the water area (see **781**).

### *7231. Mechanical Lettering Sets*

Unless the draftsman is particularly skilled in lettering, it is preferable that a mechanical lettering set be used, where practicable. There are several types of these on the market (see **4834**). For most small lettering the pen sizes recommended by the manufacturer of the Leroy sets produce too heavy a letter. The preferable size for smaller lettering, such as station names, is "No. 00."

## 724. Selection of Pencils

Although individual preferences vary somewhat, the experienced draftsman knows with which make and grade of pencil he can obtain the best results for any given requirements. All makes of drawing pencils listed in the General Schedule of Supplies, the standard list of materials contracted for by the Government, can be considered of high grade and of comparable quality, although tests have shown that a variation of approximately one grade may be found in the hardness of one make as compared with another. Gradations of any one make, however, can be depended upon to be consistent. Before being listed in the General Schedule of Supplies, drawing pencils are rigidly tested to determine whether they comply with the specifications. The leads in most pencils are made by the same process. Of those listed in the General Schedule in 1942 the Van Dyke Microtomic Graphite is believed to smudge the least and the Koh-i-noor and Turquoise pencil leads are thought to average slightly harder for the same grade than other makes. It is also the belief of some draftsmen that the Koh-i-noor leads are, on the average, of a more uniform quality.

For most pencil work on a smooth sheet, pencils of a grade no harder than 3H or 4H should be used, except for the construction of projections and the plotting of control stations by *dms.* and *dps.* (see **7411**). For these a much harder pencil should be used, extreme care being required to prevent damage to the surface of the paper. On a humid day when the paper is likely to be damp and easily indented, a pencil one grade softer should be used than is customary for the same purpose on a dry day.

Under no circumstances should a hard chisel-edged pencil be used to draw the connecting lines between positions on the smooth sheet, because this may result in rupturing the paper at the most critical place, that is, along the line of soundings. Furthermore, the indentation formed makes inking the soundings extremely difficult, because the pen catches in the indentation. A pencil no harder than 4H, sharpened to a point, not a chisel edge, should be used for this purpose.

### 725. Selection of Pen Points

The drafting pens on the General Schedule of Supplies are not uniform in quality nor are they tested as thoroughly as the pencils are. As in the case with pencils, an experienced draftsman will know with which make and type of pen he can obtain the best results for a particular style of drafting.

The Gillott crow-quill pen (No. 659) is believed to be the best all-purpose pen for fine work, especially after the point has been dressed slightly. For a draftsman who prefers a fine limber point, Gillott No. 290 or No. 291 is perhaps the best. For average work Gillott No. 170, and for heavy work such as shoreline Gillott No. 303 or No. 404, are recommended. For the very fine lines required in inking day letters and position numbers on sounding lines, a Hunt No. 104 may be preferred to the Gillott No. 290 or the crow-quill.

In 1943, because of the war, Gillott pens were not obtainable. Esterbrook pens are the best available on the General Schedule of Supplies. The numbers of comparable grades of Esterbrook pens are 62, 354, 355, 356, 357, and 358, for Gillott pen numbers 659, 291, 290, 170, 303, and 404, respectively.

### 726. Inks

Waterproof drawing inks, particularly colored inks, vary considerably in quality from year to year and no recommendations can be made at any particular time with the expectation that they will be found correct in the future. The inks listed in the General Schedule of Supplies are satisfactorily tested before listing, and it is believed that at any given date the General Schedule is, perhaps, the best guide. It does not follow, however, that if ink of one make is satisfactory in one or two colors, other colors of the same make will necessarily be satisfactory. Experience is, after all, the best guide.

Black waterproof drawing ink is the only ink which is entirely waterproof. Other colored waterproof inks are not fully waterproof and this fact should be carefully considered in connection with their use.

In the past, Higgins waterproof drawing ink has, perhaps, been found consistently better than other makes. At the present time both Higgins and Keuffel & Esser black waterproof ink comply with the federal specifications.

#### *7261. Celluloid Ink*

While ordinary drawing ink can be used on celluloid sheeting, it is preferable to use celluloid ink because it makes a more permanent bond and does not rub off or chip so easily. It can be removed with a steel eraser; light ink work can be removed with an ink eraser or an erasing machine, the latter leaving a better surface for redrafting.

Celluloid ink will be furnished by the Office on request. It is available in light, medium, and heavy grades. The medium is more generally used. The solvent in celluloid ink evaporates rapidly making it necessary to thin the ink from time to time. This is done with a special thinner, which is also available on request. A small quantity at a time should be thinned, suitable for the individual draftsman.

### 727. Erasing and Cleaning

During the construction and plotting of the smooth sheet every effort should be made to keep the sheet clean and to avoid placing unnecessary marks thereon (see **731**). Even with considerable care, a smooth sheet will eventually become slightly soiled.

Errors are occasionally made which must be corrected, and temporary notes or lines are placed on the sheet which must be removed. These erasures as well as the cleaning of the sheet require extreme care in order to avoid damaging the surface of the paper.

Most temporary pencil lines and notes, if made lightly with a 3H or 4H pencil, can be removed with an art gum eraser without damage to the paper. Penciled errors and the badly smudged places generally require the careful use of a soft red eraser of the "Ruby" or "Venus" type now on the General Schedule. Ink erasures cannot be made without some damage to the surface, but less damage is generally caused with the skillful use of an electric eraser (see **4852**) than by any other method. Hard abrasive erasers should never be used, even for the removal of ink work. Colored erasers should always be tested before use to determine whether the color rubs off, and if so, they must not be used on the smooth sheet.

The sheet in general may be cleaned by crumbling a small piece of art gum over it and gently rubbing the crumbs across the surface with a piece of clean white paper placed flat under the hand. Bread crumbs may be used for the same purpose.

## 73. PREPARATION OF THE SMOOTH SHEET

The completed smooth sheet is a valuable original document. It is preserved indefinitely in the archives at the Washington Office. The amount of care taken to protect the sheet during its construction will be directly reflected in its future longevity.

### 731. Protection of Smooth Sheet

Prior to and during the construction and plotting of the smooth sheet, the paper should be kept in as dry a place as possible, especially if the climate is at all humid. All drafting work is done much easier on dry paper.

It is inevitable that the sheet will become slightly soiled while being worked on, but there is no reason why it should be soiled excessively if a reasonable amount of care is taken to keep all parts of the sheet covered, except the small area on which work is actually being done.

Smooth-sheet paper has a specially prepared surface and every care should be taken to avoid damage to this surface. Lines should never be scratched on the paper, except short arcs necessary in constructing a projection. This damages the surface and ink *runs* in the scratches. It is equally important to avoid the indentations made by using too hard a pencil or by pressing too heavily when drawing lines, particularly the connecting lines between positions (see **724**). Smooth sheets have been received in the Washington Office with the surface cut so badly by sharp pencils that in a short time the paper cracked at these places. When this occurs, deterioration of the sheet soon follows.

Temporary construction marks and temporary notes should be kept at a minimum, and these, particularly the notes, should be made with as soft a pencil as practicable so that they may be erased without damage to the paper.

#### *7311. Rolling the Smooth Sheet*

The mounted paper used for smooth sheets is of the best possible grade and if it receives careful treatment during the making of the smooth sheet and subsequently, it should suffer comparatively little distortion. If practicable, the smooth sheet should be kept flat during the entire period of its construction. Rolling during this period is

not only harmful to the paper, but results in a curve set in the paper, which makes plotting and inking unnecessarily difficult. If the smooth sheet must be rolled at any time, it should be rolled loosely to a diameter of not less than 6 inches with the cloth-backed side of the paper on the outside.

Under no circumstances should the smooth sheet be allowed to extend over the edge of the table during plotting. This subjects the sheet to permanent creasing or bending which may result in weakening the paper to such an extent that it eventually cracks or breaks.

## 732. THE PROJECTION

The graphic record of a hydrographic survey is a smooth sheet, which in effect is a map of the area surveyed. A map is a flat-surface representation, at a given scale, of some part of the curved surface of the earth. On a map the features of the earth's surface are represented with reference to each other according to some system which will simulate their relation in nature. In order to accomplish this best, a projection is used—that is, an orderly arrangement of the terrestrial meridians and parallels on a plane surface.

No matter how small a part of the earth's surface is under consideration it is still curved, and theoretically cannot be represented on a plane with perfect accuracy. As the area increases, the distortion or the departure from nature becomes greater when an attempt is made to show it on a plane surface. It follows consequently that the meridians and parallels cannot be shown on a plane exactly as they are on the earth. Projections can be constructed in which some one or more desirable properties are mathematically exact but only at the expense of other properties. Therefore, every form of projection is at best a compromise. For practical purposes, however, it is found that as the area considered is reduced it eventually reaches a size so small that it can be represented at a given scale on a plane surface without any plottable error.

The subject of projections is treated extensively in Special Publication No. 68, Elements of Map Projection.

### *7321. The Polyconic Projection*

Various projections have been adopted by different countries and different surveying agencies within each country on which to plot the results of their surveys. The Coast and Geodetic Survey has adopted for all surveys a projection, known as the Coast and Geodetic Survey polyconic projection. All surveys must be plotted on this projection.

This polyconic projection was devised by Ferdinand Hassler, the first Superintendent of the Coast and Geodetic Survey. It is extensively used for surveys of comparatively small areas, such as those covered by the hydrographic and topographic surveys of the Bureau, because it effects a satisfactory compromise with all of the most desirable properties of map projections, because of its ease of construction, and because a general table for its use has been calculated for the entire spheroid. The projection data are based on Clarke's reference spheroid of 1866 and are contained in Special Publication No. 5, Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridian and Parallels. This publication is familiarly known by its short title, "The Polyconic Projection Tables."

The polyconic projection is the development of an area by means of successive cones tangent to the surface at successive parallels. The central meridian of any

polyconic projection is a straight line, all other meridians and all the parallels being curved lines, except for the special case of the Equator which is a straight line. The parallels are arcs of nonconcentric circles with radii of decreasing length as the latitude increases, but whose centers lie in the extension of the central meridian. The curved meridians are concave toward the central meridian in increasing amounts as the distance from the central meridian increases. Practically, in the larger scales usual in hydrographic surveying the meridians may be considered straight lines within the limits imposed by graphic methods of construction. The longitude scale is everywhere correct, but the latitude scale is strictly correct only on the central meridian.

FIGURE 144.—Polyconic projection of North America.

The accuracy inherent in the polyconic projection is a matter of some interest. Some idea of the departure from true representation is given by the following two examples. On a 1:40,000 scale projection on a sheet 31 by 53 inches in size the scale distortion in the worst part does not exceed 9 parts in 1,000,000 and the angular error does not exceed 1″ of arc. On a 1:120,000 scale projection on a sheet 42 by 72 inches in size the scale distortion in the worst part does not exceed 3 parts in 20,000 and the maximum angular error is 15″.3 of arc. It is apparent, then, that the errors of azimuth and distance on sheets usually used in plotting hydrographic surveys are of such small proportions as not to be graphically measurable.

Since the meridians of the polyconic projection are curved lines concave toward the central meridian two adjacent maps or surveys cannot be joined together in an east-west direction, because the curvatures of the marginal meridians on the two maps are in different directions.

### *7322. Verification of Scales and Straightedges*

Before beginning the construction of the projection, the meter bar and meter scales and the straightedges should be verified unless definite information of their correctness is at hand. It cannot be assumed that the scales are correct since in the past several have been discovered with appreciable errors in the divisions. Perhaps the best test that can be applied in the field is by comparison with a meter bar known to be correct. In lieu of this a comparison of the various scales and meter bars against one another will suffice (see **4821**).

Straightedges can also be tested by comparison with one another but a better test is described in **4831**.

### *7323. The Projection Lines*

The projection intervals between the meridians and parallels to be shown on a survey sheet depend on the scale and shall be according to the following table:

TABLE 24.—*Projection line intervals for various scales*

| Scale of survey | Projection line interval |
|---|---|
| 1:2,000 and larger | Every 5 seconds. |
| 1:2,001 to 1:3,000 | Every 10 seconds. |
| 1:3,001 to 1:6,000 | Every 15 seconds. |
| 1:6,001 to 1:12,500 | Every 30 seconds. |
| 1:12,501 to 1:25,000 | Every minute. |
| 1:25,001 to 1:60,000 | Every even minute. |
| 1:60,001 to 1:125,000 | Every fifth minute. |
| 1:125,001 to 1:250,000 | Every tenth minute. |

The projection is constructed in pencil. It must be verified and all of the control stations plotted by *dms.* and *dps.* (see **7411**) and checked while the lines are in pencil. Only then are the projection lines to be inked as fine solid black lines 0.15 mm in width. The lines should extend entirely across the sheet. No borders are to be placed on smooth sheets.

The numbers representing the latitude and longitude shall be drawn in black ink at the ends of each parallel and meridian. They should be 3 mm in height and should be made in accordance with figure 145, preferably with a mechanical lettering set. Those representing degrees shall be repeated every fifth minute on scales of 1:20,000 and larger; every tenth minute on a scale of 1:40,000; and every thirtieth minute on smaller scales. For scales larger than 1:8,000, where the entire area falls within a 1-degree interval, the degree number must be shown at least once on the sheet, preferably near the center, the other lines being identified by the minutes and seconds only. The numbers must be followed by the respective degree, minute, and second symbols. Degree symbols should be 1.0 mm in diameter, and minute and second symbols 1.0 mm long, all centered on line with the top of the numbers. The numbers and symbols must be checked.

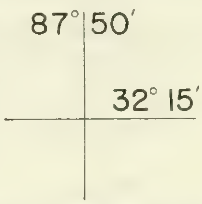


FIGURE 145.—Referencing projection lines.

### *7324. Construction of a Polyconic Projection*

The construction of a polyconic projection is a comparatively simple problem, but extreme accuracy and care are necessary. The following instruments are needed: meter bar, beam compass, straightedge, dividers, and a quarter-meter scale (see **4821**). All of the elements are found in Special Publication No. 5, "The Polyconic Projection Tables." The area to be embraced and the orientation of the sheet and the scale are found in the layout of the project (see **136**); the interval between projection lines to be drawn depends on the scale (see **7323**).

From the layout locate the intersection of the most central meridian and parallel which are to be shown, and the direction of the central meridian. The accuracy with which this needs to be done depends on how near the edge of the sheet the work will extend. If extreme accuracy is required it is generally necessary to lay off carefully the limits of the sheet on a published chart of the area, thereby locating the central intersection and orientation. In some cases even preliminary mathematical computa-

tions are necessary to ensure the inclusion of the required control points as, for example, where they fall dangerously close to opposite edges of the sheet.

Although the projection can be made by continued reference to the projection tables, it is most desirable to make a rough sketch of the projection on a sheet of paper (see **322**), noting on it all of the distances to be plotted with the meter bar and beam compass. Depending on the scale of the projection being made and the scale of the meter bar being used, these distances will of course be reduced for use directly on the meter bar. For instance, if the projection is to be 1:40,000 and the scale of the meter bar is 1:20,000 all distances taken from the tables must be halved. All data from the tables must be taken out for the latitude in which they are to be used.

Referring to figure 146, the distances $mm_1$, $mm_2$, $mm_3$, and $mm_4$, are taken from the table headed "Meridional arcs," under "Continuous sums of minutes." The distances $mx$, $mx_1$, $mx_2$, $mx_3$, $mx_4$, and $mx_5$, for each parallel are taken from the table headed "Arcs of the parallel in meters" for scales of


FIGURE 146.—Construction of a polyconic projection

1:40,000 or larger. For scales smaller than 1:40,000 they must be taken from the values of "$X$" under the table headed "Coordinates of curvature," interpolating for latitudes and longitudes intermediate between those given in the tables.

The construction is carried out by drawing the central meridian and the straight construction line $ab$ perpendicular to it. The distances $mm_1$, $mm_2$, etc., are laid off along the central meridian using the beam compass and meter bar. The straight construction lines $cd$, $ef$, $gh$, and $ij$ are drawn parallel

to *ab* through the points $m_2$, $m_4$, $m_1$, and $m_3$, respectively, and the distances $mx$, $mx_1$, $mx_2$, $mx_3$, $mx_4$, and $mx_5$ are laid off along these construction lines from the central meridian. It is especially important that these distances be laid off from the central parallel and the central meridian. The successive points $m_1$, $m_2$, etc., and $x$, $x_1$, $x_2$, etc., must never be laid off from one another.

The projection tables are now entered and "$Y$" values under the table headed "Coordinates of curvature" are found corresponding to the respective $x$-points. These values are laid off parallel to the central meridian, north of the construction lines if the projection is north of the Equator. These are usually short distances and difficult to plot. Best results can be attained by plotting an arbitrary distance, such as 100 or 200 meters on a 1:20,000 scale, south of the $x$-points and then plotting the arbitrary distance plus the "$Y$" values north from the arbitrary points.

"$Y$" values for latitudes intermediate between those given in the tables can be obtained by linear interpolation, but for longitudes intermediate between the tabular values, the following relationship should be used:

The ratio of any two successive ordinates of curvature expressed in meters, equals the ratio of the squares of the corresponding abscissas expressed in minutes or degrees.

This approximation is close enough under most conditions.

Each of the points plotted north of its respective $x$-point represents the intersection of a meridian and a parallel. Curved lines drawn through these points represent the meridians and parallels. Because it is difficult, in practice, to draw a curve of very large radius, the intersection points must be frequent enough so that the curved meridians and parallels can be drawn as a series of chords which will approximate the true curves. The projection must be left in pencil until verified and the control has been plotted. Finally the projection should be checked by measuring the intercepted distances between the adjacent meridians and parallels.

On projections of scales 1:10,000 or larger, it is generally sufficient to apply the $Y$-coordinates at the extreme meridians only, joining these points and the corresponding points on the central meridian with straight lines. The parallels so drawn are then subdivided equally for determining the intermediate meridians.

The construction of a polyconic projection is fully explained in Special Publication No. 5, "The Polyconic Projection Tables," and on pages 60-62 of Special Publication No. 68, Elements of Map Projection. The latter publication also gives the formula from which the errors of scale and area of any polyconic projection may be determined.

### *7325. Continuous Construction*

The construction of a projection must be continuous, that is, it must not be begun and then laid aside to be resumed at a later date. It should be completed and checked on the same day, if possible. Construction on days of excessive humidity or excessive dryness should be avoided. When possible the projection should be made at a time of day and during a period of weather when the atmospheric conditions are stable and nearly average for the conditions under which the smooth sheet is to be used. It is important during construction that the projection be not exposed to the direct rays of the sun.

### *7326. Verification of the Projection*

All details of the construction of the projection must be checked. This must be done while the projection is still in pencil, and must consist of a verification of the values taken from the polyconic projection tables and a complete check by measurement of the construction of the projection. Finally, corresponding diagonal distances should be compared with one another. It is to be noted that the polyconic projection is symmetrical with respect to the central meridian. Therefore, the diagonal distance between any two intersections on one side of the central meridian is equal to the diagonal distance between two corresponding intersections on the opposite side of the central meridian. A good construction check is a comparison of the long diagonal distance from

the northeast to the southwest corner through the construction center with the corresponding distance from the northwest to the southeast corner.

The verification must be made the same day that the projection is constructed and, if practicable, immediately following the construction.

### 7327. *Ruling Machine Projections*

Hand-ruled projections, carefully constructed, are usually of as great accuracy as is warranted when drawn on cloth-mounted paper. The Coast and Geodetic Survey has a projection ruling machine designed especially for ruling precise projections on mediums subject to little or no dimensional change, such as aluminum-mounted paper, aluminum plates, copper, and glass negatives. If practicable, all projections on such mediums should be made on the machine. It is not necessary to describe the details of the machine, except to say that projections of any type can be ruled on it, limited in size to 38½ by 56½ inches and limited approximately by the curvature required in a 1:500,000 scale conic projection.

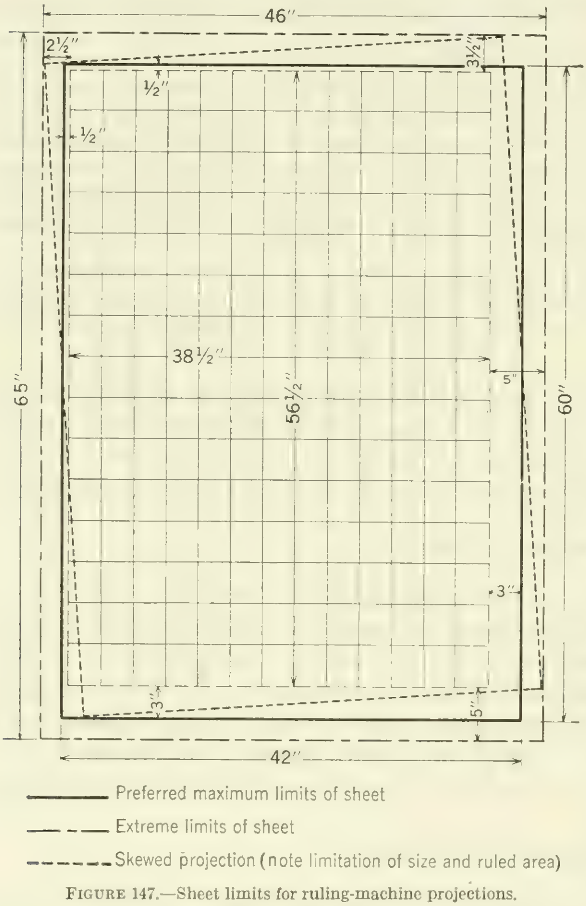



FIGURE 147.—Sheet limits for ruling-machine projections.

Chiefs of Party who wish machine-ruled projections should forward their requests sufficiently in advance to reach the Washington Office at least 3 weeks prior to the date they wish them shipped to the party. Such requests must always be accompanied by rough layout sketches showing the sheet limits by latitude and longitude, the scale, and the orientation of the projection if it is not parallel with the sheet edges. The polyconic projection will be assumed unless otherwise specified.

The size of a projection that can be drawn on the ruling machine is limited by a rectangle 38½ by 56½ inches whose sides are parallel to the projection lines. The sheet itself, however, can extend somewhat beyond these limits, but ordinarily should not exceed 42 by 60 inches (see fig. 147). In special cases a sheet 46 by 65 inches can be used. When projections larger than 38½ by 56½ inches are required, the lines must be extended by hand from the part ruled on the machine, which cannot be centered.

Where a skewed projection is to be ruled, the size of paper is also limited by the above dimensions, i. e., measured parallel to the projection lines, diagonally opposite corners of the sheet cannot be separated more than 46 inches in one direction nor 65 inches in the other direction (see fig. 147).

### *7328. Plane Coordinates*

Plane coordinates are not used by the Coast and Geodetic Survey for plotting the results of hydrographic surveys, although they are used for this purpose in many foreign countries and are used in this country by various agencies for plotting all types of surveys.

There are various types of plane and rectangular coordinates. Three principal types are now in use in the United States:

(*a*) A rectangular system in which the plane of projection is a tangent plane, and the curvature of the earth is neglected; that is, the distances and angles measured in the survey are considered to have been measured on a plane surface.

(*b*) A system of rectangular coordinates in which the plane of projection is a tangent plane, but correction or adjustment is made for the curvature of the earth.

(*c*) The official systems of State coordinates on the Lambert conformal and the transverse Mercator projections devised and computed by the Coast and Geodetic Survey in 1933 and 1934.

In each of the above systems the coordinates are referred to two reference axes at right angles to one another, one of which almost invariably coincides with the true meridian. By convention the $X$-coordinate of a position is its distance east or west of one reference axis, positive where east and negative where west, and the $Y$-coordinate is its distance north or south of the other axis, positive where north and negative where south.

In coordinate systems of type (*a*) it is usual to select some point on the earth's surface as a point of origin. This may be a well-known landmark, the geographic position of which may or may not be known, but it is usually a geodetic station the latitude and longitude of which have been determined by the geodetic control surveys of the country. In such a system the area covered must be small and the part included is considered to be a true plane, and the results of the survey are plotted on the system without correction or adjustment for the curvature of the earth.

To coordinate such a survey with the nautical charts or the surveys of this Bureau, it is necessary that the latitude and longitude of the point of origin and the azimuth of one of the reference lines be known; or these data may be derived from the known latitudes and longitudes of other points and azimuths in the system, whether or not one of them is taken as the point of origin. For coordination it is preferable that the latitude and longitude of several widely separated points on the survey be known so that not only can the survey be coordinated, but its scale may be determined independently. (See **2361**.)

For systems of rectangular coordinates of type (*b*) the points on the earth's surface are corrected for curvature so that the plane coordinates resulting therefrom have an accuracy of 1 part in 50,000 at a distance of 25 miles from the origin of the system. In this method of computation the plane coordinates are derived directly from the differences in latitude and longitude between some chosen origin and the given station. These differences are transformed directly into $X$- and $Y$-coordinates by the use of tables given in Special Publication No. 71, Relation Between Plane Rectangular Coordinates and Geographic Positions. This system approximates an equidistant azimuthal projection on a tangent plane and it is sufficiently accurate to cover a considerably larger area than can be covered in type (*a*). In no case, however, should it extend more than 20 or 25 miles from the origin.

The official State coordinate systems of type (*c*) were devised and computed by the Coast and Geodetic Survey in 1933 and 1934. One system with one point of origin

is used for each State, where practicable, although in the larger States two or more systems were necessary. These have been computed on two different types of projection: the Lambert conformal conic for those States of an east-west extent proportionately great as compared to their north-south extent; and the transverse Mercator projection for those States with a proportionately great north-south extent. The coordinates on the State systems have been computed for all geographic positions adjusted since 1935 and these are published in the official publications of the triangulation of the country.

Details of these systems, the methods of making the computations and the methods of plotting various types of surveys thereon, are given in several publications. They are given in brief in Serial No. 624, Computation of Traverse by Plane Coordinates, and in fuller detail in Special Publication No. 193, Manual of Plane Coordinate Computation; Special Publication No. 194, Manual of Traverse Computation on the Lambert Grid; and Special Publication No. 195, Manual of Traverse Computation on the Transverse Mercator Grid.

For the coordination of surveys on the systems in type (*c*) with hydrographic surveys of this Bureau, no information is needed except the knowledge that the survey is on one of the official State systems and which system.

## 733. Hydrographic Sheets From Air Photographic Surveys

Where the shoreline and hydrographic control originate with air photographic surveys (see **239**) the information for the boat and smooth sheets will be furnished by the Washington Office in the form of reversed tracing-paper prints, ozalid prints, printed sheets, or map projector transfers. The form used will depend upon the conditions peculiar to the project and will be stated in the project instructions.

The short descriptions of stations, for the information of the hydrographer, will be furnished on ozalid prints to be used by the hydrographic party when recovering the stations and building the signals (see **2392**).

### *7331. Reversed Tracing Paper Prints*

Ordinarily the air photographic survey drawings are forwarded to the Washington Office as soon as the location of the shoreline and the hydrographic control is completed. These are reproduced in the Office to the same scale as the hydrographic surveys and reversed copies are printed in black on tracing paper and furnished the hydrographic parties. The ink used is slow drying and usually the print used in preparing a boat sheet can also be used for preparing the smooth sheet some months later.

The transfer of the shoreline and control is effected by superimposing the tracing (inked side down) on the boat sheet or smooth sheet, so that corresponding projection intersections are in coincidence, and burnishing down the details. Adjustments for differences in the projections can be made by small shiftings of the tracing (see **7413**).

If the ink has dried before the smooth sheets are prepared, additional tracing-paper prints will be furnished on request.

### *7332. Ozalid Prints*

In some cases where the air photographic surveys are made at exactly the same scale as the hydrographic survey and when sufficient time is not available to prepare reversed tracing-paper prints, ozalid prints will be furnished the hydrographic party for transfer of the shoreline and control.

Ozalid prints are photographic contact prints prepared in much the same manner as blueprints. The developed print shows a colored line on a white background. These prints are developed by a dry process and have a low percentage distortion. They are satisfactory copies from which to transfer shoreline and control points, but it is necessary that the hydrographic party make a pencil tracing for such transfer (see **7413** and **7561**).

### *7333. Printed Hydrographic Sheets*

Where the hydrographic sheet layout can be made to conform approximately to the air photographic sheet layout, and where there are numerous stations and intricate shoreline details, printed smooth sheets and boat sheets are practicable and economic, and will be furnished to hydrographic parties. The copies are printed at the scale of the hydrographic surveys and on the same cloth-backed paper ordinarily used for boat sheets and smooth sheets. All details are reproduced in black, including triangulation and topographic station symbols, in addition to the projection and topography.

The positions of the stations need not be checked by the field party. The symbols for the topographic stations shall be left in black on the smooth sheets, but may be encircled with additional 3 mm red circles on the boat sheets, if this is found desirable. The triangulation symbols shall be left in black. Topographic station names shall be assigned by the hydrographic party, and shall be shown in red on both the boat and smooth sheets. (See also **744**.)

### *7334. Map Projector Transfers*

In some cases, although the boat sheets and smooth sheets are prepared in the Washington Office, photolithographic reproductions are not made because of insufficient time, or because the air photographic surveys are on an odd scale and a printing plate is not yet available, or when their limits differ greatly from the hydrographic survey. In such cases the projections are made on the projection ruling machine, and the shoreline and control points are transferred (and checked) from the air photographic surveys by means of the map projector (see **4854**). The transfer is usually made in pencil and shall be inked by the field party. A data record showing how the projection was made, and how and by whom the shoreline and stations were transferred and checked is forwarded to the field party with each smooth sheet. This record shall be included in the Descriptive Report for the sheet (see **842*E***).

## 734. Projections for R.A.R. Sheets

The best grade of well-seasoned paper shall be used for an R.A.R. smooth sheet. The projection is constructed just as any other projection is, but immediately after its completion and verification and the plotting and verification of the R.A.R. stations, and before any inking is done, the *distance circles* must be drawn (see **7341**), in order to avoid complications due to distortion of the paper. Obviously, such projections should not be requested from the Washington Office.

### *7341. R.A.R. Distance Circles*

In contrast to other methods of hydrographic control, positions determined by Radio Acoustic Ranging (described in chapter 6) are based on distances from the R.A.R. stations and these are sometimes quite long. To facilitate plotting these distances and to take into account any distortion which occurs in the smooth sheet after the projec-

tion is made, segments of concentric circles are drawn on the sheet from each R.A.R. station as a center, covering the area in which bomb returns were received from the respective stations. These circles are termed *distance circles* to distinguish them from the short *distance arcs*, which are drawn only in the immediate vicinity of each R.A.R. position (see **763**).

All distance circles are plotted in units of time intervals from a given station based on an assumed velocity of sound of 1,460 meters per second. The spacing of the circles on the sheet should be according to table 25.

TABLE 25.—*Distance circle intervals for various scales*

| Scale of survey | Distance circle interval |
|---|---|
| 1:40,000 | Every 3 seconds. |
| 1:50,000 to 1:80,000 | Every 5 seconds. |
| 1:100,000 to 1:160,000 | Every 10 seconds. |
| 1:200,000 | Every 15 seconds. |

The unit of measurement *second* is used here to mean a second (time) of sound travel through sea water. Thus, a circle representing 5 seconds of sound travel would be plotted a distance of 1,460 x 5 = 7,300 meters from the station at the scale of the survey.

Preparatory to placing the circles on the sheet, and preferably even before the projection is begun, the boat sheet should be studied to determine the area in which bomb returns were received from each R.A.R. station. This will be the area through which the distance circles should be drawn. It is important that this instruction be carefully followed in order to avoid unnecessary confusion where many stations are used on a sheet. A table should also be prepared in advance giving the lengths in meters of the various radii, computed at the plotting velocity of 1,460 meters per second and converted to the scale of the meter bar being used. This table is then used for setting the distances on a beam compass.

To plot the circles the successive radii lengths are pricked lightly on the smooth sheet. This should be done at two or more radial directions from the R.A.R. stations, so that each distance circle when drawn may be checked as it passes through the pricked points. To avoid a repetition of measurements, each distance, as set on the beam compass, should be plotted from every R.A.R. station where it will be needed.

After the plotting of the radii has been checked, the distance circles are drawn in blue ink through the pricked points, using a fine light line. The distances in seconds may be placed on the circles in pencil for temporary convenience.

It is essential that the smooth sheet be kept absolutely flat while the radii are being plotted and the circles are being drawn. This can be accomplished, in the first case, by laying a straightedge on the sheet from the station to the pricked points, and in the second case, by having an assistant slide a straightedge along the sheet paralleling the beam compass, immediately in advance of or behind it. A clean stainless steel straightedge, or one whose underside is covered with a clean piece of paper, must be used in order to prevent soiling the smooth sheet.

The continued use of the beam compass at the R.A.R. stations tends to enlarge the station holes. To avoid this a small circular piece of thin celluloid is temporarily placed over each station with Scotch tape, so that the compass point rests on the celluloid instead of on the paper. Where this is done the pricked point in the celluloid must be precisely over the plotted position on the smooth sheet. Pencil lines should be drawn at right angles through the plotted position on the smooth sheet, by which the celluloid, on which similar lines at right angles have been drawn or finely etched, may be correctly superposed. If only a few distance circles are to be drawn from any one station the celluloid may be dispensed with, if caution is taken to avoid an excessive downward pressure on the beam compass.

Two R.A.R. control stations are frequently used at locations very close to one another. Confusion would result if concentric distance circles were drawn from both of these as origins. Instead, the distance circles are drawn from that station from which the larger percentage of R.A.R. distances was obtained during the survey. The method of plotting in such cases is explained in **7631**.

There will be occasional cases where an R.A.R. station used for control is beyond the limits of the sheet. If such a station is within reach of a beam compass, it may be plotted by using a computed distance and direction from a latitude and longitude intersection on the projection. A specially long beam compass may be required for drawing the distance circles (see **3741***c*1).

Distance circles involving radii too long to be drawn with a beam compass may be constructed by computing the rectangular coordinates of points on the circles and drawing the circles by using standard curves. The formulas for computation are the same as for constructing "circle" sheets by the computation method except that the origin of coordinates is taken as the intersection of two distance circles on the sheet, the $Y$-axis being the azimuth from the intersection to an R.A.R. station and the $X$-axis being normal thereto at the same point. (See **3741***c*2.)

After the distance circles have been drawn on the smooth sheet and the other control stations plotted and checked, the projection lines are inked (see **7323**). Control station names in the water area must be left in pencil for subsequent inking (see **7443**).

### 735. Plotting Large-Scale Offshore Surveys

Large-scale offshore surveys using three-point fix control cannot usually be made or plotted with the degree of accuracy required, if conventional methods of plotting are used—that is, with a three-arm protractor. Instead, the "circle" sheet method is used in which the observed angles are plotted by means of their loci, systems of which have been drawn in advance on the boat sheet or smooth sheet. A full discussion of this method of surveying and of the method to be used in preparing such sheets is given in section **37**. The smooth plotter should familiarize himself thoroughly with the method before beginning work on such a smooth sheet.

After the arcs have been plotted and verified, they should be inked in blue using a fine light line similar to that used for R.A.R. distance circles (see **7341**). The arcs should be identified by inking the degrees and minutes in the same color near the ends of the arcs. It is unnecessary and undesirable to ink all the arcs used in protracting

the positions. The purpose of inking is to give permanence to selected arcs, so as to facilitate future identification of the positions. The smooth-sheet plotter should bear this in mind when selecting the arcs to be inked. In general, a spacing of about 3 inches between inked arcs will be satisfactory. Only those portions of the arcs in the sounded area should be inked.

## 736. Changing Datum of Survey Sheet

To correlate the results of two surveys, it is first necessary to bring the two to the same geographic datum (see **2171**). This makes it possible to compare corresponding areas by means of the projection lines on the sheets.

Practically all of the recent surveys of the Bureau in continental United States are based on the North American datum of 1927, but many prior surveys are still on the North American datum or some independent datum. To change the datum of a survey sheet the usual practice is to apply corrections to the projection on the sheet. When copies of old surveys are furnished to field parties, the latest datum is usually shown on the sheet. The procedure given below describes how this may be accomplished under various conditions. Where the datum on a survey sheet has to be corrected in the field, the data available will generally determine the method to be used.

There are two methods of applying a datum correction to a survey sheet, a numerical one (**7362**) and a graphic one (**7363**).

### *7361. Distortion Factor*

Before datum corrections can be applied, the distortion factor of the sheet must be determined in both a north-south and an east-west direction. This is done by comparing the scaled distances between projection lines on the sheet with the corresponding values given in Special Publication No. 5, "Polyconic Projection Tables" (see **7324**). The distortion factor is determined from the relation:

$$\frac{\text{Tabular value} - \text{Scaled value}}{\text{Tabular value}} = \pm \text{Distortion factor}$$

Several distances in each direction should be measured in order to obtain a mean factor and to ensure against errors in the original projection. The distortion factor should be applied to every distance that is to be plotted on the sheet. To reduce measurements on the distorted sheet to true values the following relation should be used:

$$\frac{\text{Tabular value} - \text{Scaled value}}{\text{Scaled value}} = \pm \text{Correction factor}$$

### *7362. Numerical Method*

In the numerical method three widely distributed triangulation stations on the sheet are selected, whose geographic positions on the N.A. 1927 datum are available. Identify these stations on the datum of the projection in the old registers in the Surveys Branch of the Chart Division, or in any of the publications of the Bureau, and check their geographic positions with the positions plotted on the sheet. The mean of the differences between the values on the two datums is the correction to be applied to the projection on the sheet. The differences for the three stations should nearly equal each other. If a wide variance is found, an investigation should be made for possible errors in the computations or for failure to identify common stations on the two datums.

Great care must be taken to see that the correction is applied in the proper direction. The following rule will be found helpful in determining the direction:

If the latitude (N.) and longitude (W.) on the old datum are greater than the corresponding values on the new datum, then the new projection will be to the north and west, respectively, of the old projection. If the old values are smaller than the new ones, it will be to the south and east.

From this the direction of the correction for other relationships can be readily determined. To avoid errors of application in plotting, a sketch should be made, showing the relationship of the two datums to one of the selected triangulation stations, with the corresponding latitudes and longitudes indicated.

The new datum should be marked by short intersections at not less than two projection intersections on the sheet and should be shown in colored ink, preferably red. At one of the intersections the name of the datum, the latitude and longitude, the initials of the cartographer making the correction and of the verifier, and the date the correction was made, should be noted in colored ink. (See fig. 148.)

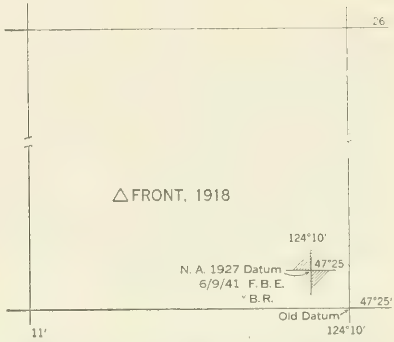



FIGURE 148.—Change of datum of survey sheet—by numerical method.

*Example:* In figure 148, the latitudes and longitudes of △ FRONT, 1918 on the old and new datums are as follows:

| *North Latitude* | *West Longitude* |
|---|---|
| 47° 25′ 450 meters (old datum) | 124° 10′ 900 meters (old datum) |
| 47° 25′ 300 meters (N.A. 1927 datum) | 124° 10′ 750 meters (N.A. 1927 datum) |
| 150 meters difference | 150 meters difference |

Applying the above rule, the new projection (N.A. 1927 datum) is found to be to the north and west of the old projection. Therefore, the intersection of latitude 47° 25′ N. and longitude 124° 10′ W. on the new datum is obtained by laying off the distances 150 meters (corrected for distortion) in a north and in a west direction from the old datum.

*Reference station on the sheet.*—If the latitude and longitude of one of the plotted stations is recorded on the sheet (see **746**), the correction may be obtained by subtracting from them the corresponding values on the N.A. 1927 datum. For field application, where photographic copies of old surveys are used, the single correction thus obtained is sufficiently accurate for use on the entire sheet, but in the Office where the original sheet is available, additional stations should be used and a mean correction obtained in accordance with the procedure outlined above.

The numerical value shown on the sheet should always be checked against the plotted position of the station before using it for determining a datum correction.

### *7363. Graphic Method*

This method of correcting the datum on a survey sheet is applicable under three conditions: (1) as an alternative to the numerical method, (2) where geographic positions of the stations on the datum of the sheet can be found neither in the old registers (see **7362**) nor in any of the publications of the Bureau, and (3) where the old registers are not available, as is usually the case in the field.

Select three well-distributed stations on the sheet, the geographic positions of which are available on the N.A. 1927 datum. Determine the *dm.* and *dp.* of each station (see **7411**) from the projection lines nearest to it (this will mean using the

back *dms.* and *dps.* in some cases), and with these values as radii from the plotted position of the station as a center, swing short pencil arcs in the proper directions. Draw pencil lines tangent to these arcs and parallel to the latitude and longitude lines on the sheet. The intersection of these lines will give the position of the new datum. Carefully scale the offsets $\Delta\phi$ and $\Delta\lambda$ from the old datum on the sheet. (Fig. 149 illustrates the application of this method to the example given in **7362**.)

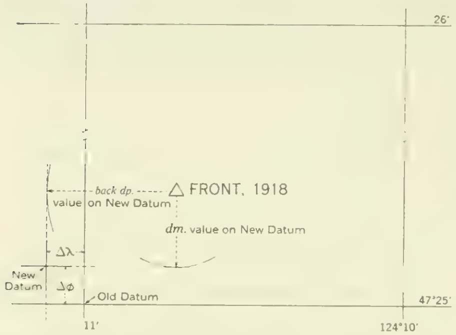


FIGURE 149.—Change of datum of survey sheet—by graphic method.

Follow the same procedure with the other selected stations and compare the offset values obtained in each case. If they do not differ by a plottable amount, accept the intersections as determined, otherwise use a mean of the values. Any appreciable differences should be investigated. The method of designating the new datum on the sheet is the same as for the numerical method.

### *7364. Lost or Unrecoverable Stations*

Stations are sometimes lost or have become unrecoverable and cannot therefore be included in the triangulation to connect them with the new datum. Where a survey sheet contains such stations only, then the relationship between the old and new datums must be obtained from stations on adjoining sheets for which the new datum values are available. A mean of the corrections derived from the adjoining sheets should be used.

The present plan of the Bureau is to include, in the published triangulation data for the coastal states, a list of lost stations with their geographic positions (unadjusted) on the North American datum of 1927. While such values are not to be used for extending triangulation, they are adequate for coordinating old and new surveys. These volumes should be consulted before applying datum corrections to a sheet.

## 737. PROJECTION CONSTRUCTED AFTER SURVEY

It becomes necessary occasionally to execute a survey and complete the smooth plotting prior to the determination of the geographic positions of the control points, as where the local triangulation has not been connected to the main net of triangulation or where astronomic observations have not been made. In such cases the control points are plotted on the boat sheet and the smooth sheet either by angles or distances. Many of the early surveys of the Bureau were made in this manner. (See **392** and **393**.)

In constructing a projection on a survey sheet that has no projection, the distortion of the sheet is one of the important elements to consider and upon the accuracy of its determination will depend the accuracy of the projection. Paper does not always distort uniformly and the shrinkage or expansion should be determined in both a north-south and an east-west direction and a factor applied to all measurements to be laid down on the sheet (see **7114**). It should be remembered, however, that the smaller the distance to be plotted the less will be the error of distortion so that in laying down projection lines from plotted triangulation stations, corrections may be avoided by selecting stations close to the lines to be constructed.

Whenever a smooth sheet is prepared in advance of the position computations, two distances not less than one-half meter in length should be plotted on the sheet at right angles to each other, along the bottom and along the right-hand edge. The ends of these distances should be marked with small inked circles and the distances at the scale of the survey indicated. This will permit checking the distortion at any time and simplify the future application of a projection.

There are two methods of reconstructing a projection on a survey sheet. One is a rigid method applicable to small-scale surveys and the other is a graphic method applicable to large-scale surveys. In both methods the essential problem is the determination of the cardinal lines of the projection, namely, the central meridian and the central construction line.

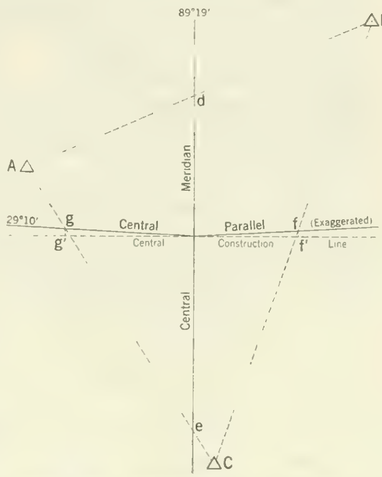



FIGURE 150.—Construction of a polyconic projection on a completed survey sheet—for small-scale surveys.

### 7371. *On Small-Scale Surveys*

For surveys on scales smaller than 1:10,000 the following method is used:

(1) Select three triangulation stations, *A*, *B*, and *C* (fig. 150) so situated with respect to the central meridian that the distance *de* will cover more than half the latitude extent of the sheet. Two of the stations should be selected, if possible, in about the same latitude (see (6) below). From the scaled lengths of *BA* and *CA* and the corresponding computed lengths (make inverse computations for these if they are not in the triangulation data), determine the distortion factor along each line (see **7361**).

(2) Select the central meridian (as near to the middle of the sheet as possible) and compute the distances *Bd* and *Ce* and the latitudes of the points *d* and *e*.

This is accomplished on Form 27, Position Computation, Third-Order Triangulation. Since both the distance and latitude are involved in the position computation formulas, a trial-and-error method is used. A value is assumed for the required latitude ($\phi'$) and from the known longitudes ($\lambda$) and ($\lambda'$) of station *C* and the central meridian, respectively, and the known azimuth ($\alpha$) of the line *Ce* (obtained either directly from the triangulation data or from the inverse computation), the distance ($s$) is computed from the longitude formula. This distance is then used in the latitude formula and the latitude increment or decrement ($\Delta\phi$) is obtained. This computed $\Delta\phi$ may not agree with that derived from the assumed latitude ($\phi'$), but by repeated assumptions a value for $\Delta\phi$ will be obtained that is in absolute agreement with the assumed latitude.

To obtain a close first approximation, a sketch should be drawn at about one-fifth the scale of the sheet, using a rectangular grid and using as units of measurement the values of a minute of latitude and longitude at the center of the sheet. From this sketch the latitude where a given line crosses the central meridian can be scaled and this value used as the first assumed value in the computation.

(3) Plot points *d* and *e* along lines *BA* and *CA* correcting each computed distance for the distortion determined along the respective lines. Through *d* and *e* draw a straight line for the full length of the sheet. This is the *central meridian* of the projection.

(4) Scale the distance *de* on the sheet and from the computed latitudes obtain from the polyconic projection tables the true distance. From these two values the distortion in a north-south direction is determined.

(5) On the central meridian lay off the tabular distance (corrected for distortion) from point *d* or *e* to the central parallel and at this point construct a perpendicular to the central meridian extending the full east-west length of the sheet. This is the *central construction line.*

(6) From here the problem is the ordinary one of constructing a polyconic projection as given in **7324**. The distortion factor to be applied to east-west measurements may sometimes be obtained from the disposition of the selected triangulation stations (see (1) above).

The projection should be checked against every triangulation station on the sheet. Small differences in latitude or longitude may be due to unequal distortion of the sheet. In such case the projection should be made consistent with the triangulation even though this results in a slightly skewed projection.

*Determining east-west distortion.*—If the east-west distortion of the sheet is not available from the disposition of the triangulation stations on the sheet, it can be determined in the following manner:

(1) Compute the longitude crossings of the lines *CB* and *CA* (fig. 150) on the central parallel or any other parallel that will give a distance long enough to determine a good distortion factor.

This is accomplished on Form 27 in a manner similar to that described in (2) above for determining the latitude intersection. With the azimuth of the line *CB* as previously determined and the known latitude increment or decrement ($\Delta\phi$), a value for ($s$) is found by trial and error that will make the sum of the latitude terms in the computation formula equal to ($\Delta\phi$). From this value of ($s$) the required longitude ($\lambda'$) is computed.

A close first approximation for the distance ($s$) can be obtained by making $\Delta\phi$ equal to the 1st term in the latitude formula (neglecting the 2nd term) and with the ($s$) value thus found, the 2nd term is computed. A new value for the 1st term is then found that will make the sum of the two terms equal to $\Delta\phi$. The resulting value of ($s$) is then used in the longitude formula to obtain ($\lambda'$).

Because of the distances usually involved, it will seldom be necessary to carry the computation beyond the 2nd term in the latitude formula.

(2) Plot the computed distances *Cf* and *Cg* (corrected for distortion) along lines *CB* and *CA* and at points *f* and *g* draw short lines parallel to the central meridian. Lay off to the south (in north latitude) on these lines the *Y*-coordinates from the polyconic projection tables for the appropriate longitude distance and obtain points $f'$ and $g'$. The scaled distance between these points compared with the tabular distance as determined from their *X*-coordinates will give the distortion factor in an east-west direction (see **7361**).

If a linear interpolation of the *X*-coordinate values given in the table is not close enough for any latitude $\phi$ and difference of longitude $\Delta\lambda$, then the interpolation should be made by second differences or the values computed from the formula:

$$X \text{ (in meters)} = \frac{6{,}378{,}206}{(1-0.00676866 \sin^2 \phi)^{1/2}} \cot \phi \sin (\Delta\lambda \sin \phi)$$

The error due to neglecting second differences is no greater than one-eighth their value.

Wherever possible, advantage should be taken of the location of some of the triangulation stations to reduce the amount of computation for determining the east-west distortion. For example, in figure 150, the parallel through station *A* can be used instead of the parallel through *g*, thereby making it unuecessary to compute the longitude of *A*.

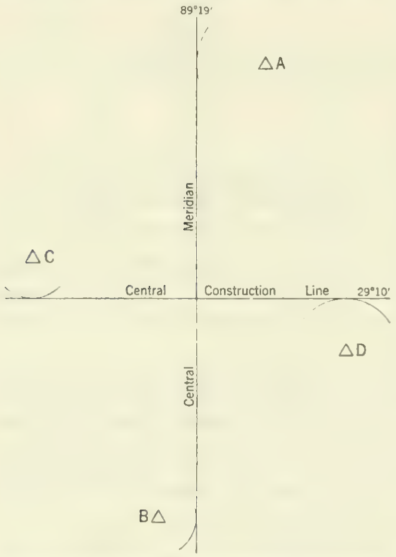


FIGURE 151.—Construction of a polyconic projection on a completed survey sheet—for large-scale surveys.

### *7372. On Large-Scale Surveys*

For small areas such as those covered by the large-scale topographic and hydrographic surveys of the Bureau, the polyconic projection is practically identical with the rectangular projection or a modification thereof (projection with converging meridians); therefore in reconstructing a projection on surveys of scale 1 : 10,000 or larger, the following graphic method can be substituted for the more rigid method described above.

(1) After the distortion of the sheet has been determined, from comparisons between scaled and computed distances, select two triangulation stations, *A* and *B* (fig. 151), near the north and south extremities of the sheet and as close to the center of the sheet as possible. From the "Arcs of the parallel" in the polyconic projection tables, obtain the distance from each station to the central meridian and with these distances (corrected for distortion, see **7361**) as radii and the stations as centers swing arcs. Draw a line tangent to these arcs for the entire length of the sheet. This line is the *central meridian* of the projection.

(2) Select two other triangulation stations *C* and *D* near the east and west extremities of the sheet and as close to the central parallel as possible. From the "Meridional arcs" in the polyconic projection tables obtain the distance in meters from each station to the central parallel. To these distances add or subtract the *Y*-coordinates from the tables corresponding to the difference in longi-

tude between the central meridian and each station. (For north latitude, add if the station is above the central parallel and subtract if below. For south latitude the reverse is true.)

(3) With the distances thus obtained (corrected for distortion) as radii, swing arcs from stations $C$ and $D$ in a direction toward the central parallel. Draw a line tangent to these arcs for the entire width of the sheet. This line will be perpendicular to the central meridian and will be the *central construction line* of the projection.

(4) The remainder of the projection is constructed according to the method given in Special Publications No. 5 and 68 for large-scale projections.

### 7373. *Modified Methods*

The above two methods illustrate the general principles involved in the problem of constructing a projection on a smooth sheet subsequent to its completion. It may sometimes be necessary to modify the methods described because of special conditions encountered. For example, where all the triangulation stations are on one side of the central meridian, the rigid method is not applicable in its entirety and a combination of the two methods must be used. In such cases the central meridian is determined graphically and the intersection of the central parallel with a line between two of the triangulation stations is computed. The $Y$-coordinate of the intersection is plotted and a perpendicular erected to the central meridian, the intersection of the two being the center of the projection.

Even in a small-scale survey, if the longitude extent is small enough, the curvature of the parallels may be neglected and the graphic method will give the required accuracy.

There are also cases where the survey is a planetable traverse (**392**) or a running ship survey (**3941**) in which the azimuths and distances at one end are comparatively accurate but which decrease progressively in accuracy toward the other end. Where such a survey is plotted without a projection and selected stations are subsequently located by triangulation and an attempt is made to place a projection on the sheet adjusted to the triangulation stations, a single harmonious projection could not be constructed. If the work is not to be replotted, then the only way to bring the entire survey into harmony geographically is to place a discontinuous projection on it, each portion being based on the triangulation in its vicinity.

In adapting any of the methods to a particular problem in hand, the two considerations to be kept in mind are the theory of the polyconic projection and the means available for determining the distortion of the sheet.

## 74. PLOTTING THE CONTROL

After the projection has been made and checked, the next step in the preparation of a smooth sheet is the plotting of the control (see section **21**). There are two general classifications of control insofar as a hydrographic survey is concerned. First, the fixed control, also commonly known as shore control (see sections **22**, **23**, and **24**); and second, the floating control (see section **25**). Before plotting is begun, a selection should be made from the control falling within the limits of the smooth sheet and only those stations plotted that were actually used to control the hydrography. The boat sheet may be used as a guide (see **3245**).

The control stations must be plotted with the utmost care and accuracy, since inaccuracies in their positions may result in errors in the positions of the soundings, the errors increasing with the distance from the control stations. Stations whose geographic positions are known should be plotted with an accuracy that will ensure no plottable error at the scale of the survey sheet.

## 741. Plotting the Shore Control

Shore control may be divided into three classes according to the method and accuracy of determination (see **211**). First, is the control located by triangulation; second, that located by topography; and third, the remainder, which is located by the hydrographic party, usually by sextant angles. Of these three types of control the latter, the hydrographic stations, are invariably located for the purpose of controlling the hydrographic survey. The topographic stations are almost always located for this purpose, especially if the topographic survey immediately precedes the hydrographic survey. The triangulation stations, however, have often been located for the purpose of controlling the topography or as part of an arc of triangulation, and may or may not be valuable in controlling the hydrography.

There are several methods in use for plotting the shore control on the smooth sheet, depending upon the form in which the data are available. These methods are described in the following items.

Cuts, angles, and distances may often be combined in various ways to furnish positions of control stations. These are described in chapter 2. Such determinations are usually best plotted with the three-arm protractor in the manner described in **4534,** if computations are impracticable.

### *7411. Plotting by Dms. and Dps.*

The data for plotting triangulation stations are usually furnished on Form 28*B*, Geographic Positions. The latitude and longitude in degrees, minutes, and seconds are given for each station, as well as the distances and azimuths between stations. The equivalents in meters of the seconds of latitude and longitude are also given for stations along the coast and these are known as the *dms.* (meridional differences) and *dps.* (parallel differences), respectively, of the stations. Thus, if the position of a station is given as latitude 54°44′34″.189 N. (1,057.2 meters), longitude 130°56′42″.362 W. (756.5 meters), its *dm.* is 1,057.2 meters north of the 44-minute parallel, and its *dp.* is 756.5 meters west of the 56-minute meridian.

To plot a triangulation station, the quadrilateral on the projection within which the station falls is first identified. With a pair of dividers and a metric scale (see **4821**), plot its *dm.* near each meridian line and mark with a fine prick point. Connect the two points thus plotted with a fine pencil line, using a chisel-edged 6H pencil. Plot the *dp.* of the station along this line and mark with a fine prick point. This will be the position of the station provided there is no distortion in the paper.

As a check of the plotting, and to compensate for any possible distortion, the station must also be plotted from the north parallel and the west meridian of the quadrilateral. These distances are the *back dm.* and *back dp.* for the station, and if not already available, they may be obtained by subtracting the *dm.* and *dp.* values from the value of 1 minute of latitude and longitude, respectively, as given in the polyconic projection tables for the latitude of the station. If the sheet contains an appreciable amount of distortion the plotted distances will result in two pairs of points, each pair closely adjacent. The true position of the station will be at a distance from the points proportional to their respective distances from the projection lines. (See fig. 152.)

The position of the station should be marked with a fine prick point and identified temporarily by a small circle and the name of the station, both in pencil.

In plotting by *dms.* and *dps.* do not use the intersections of meridians and parallels to plot from, but use points on the parallels or meridians slightly offset from the intersections. A magnifying glass should always be used for setting the dividers on line and for selecting the final position of the station. The beam compass should be used if the distances are too long to plot accurately with dividers.

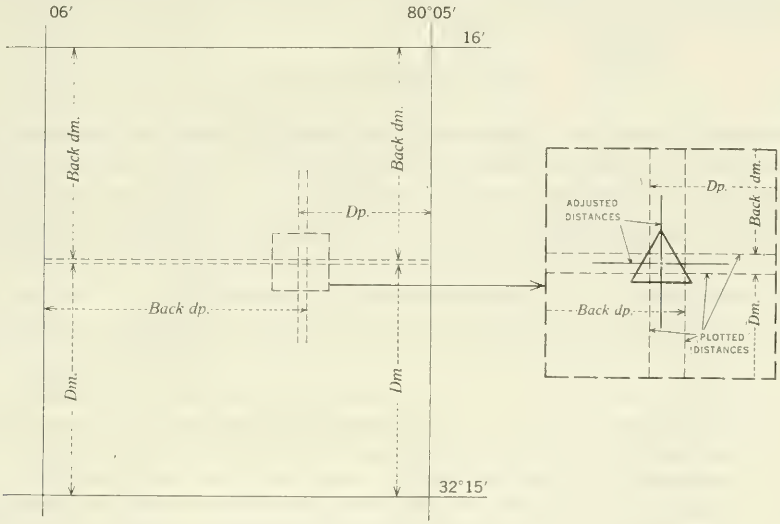



FIGURE 152—Control stations plotted by *dms.* and *dps.* on a distorted sheet.

On recently constructed smooth sheets in which there is no distortion, triangulation stations should always be plotted by the *dm.* and *dp.* method. The plottings may be checked with the "latitude and longitude scales" (see **7412**).

Other types of control are often plotted by *dms.* and *dps.*, especially when their positions are available only in this form.

### *7412. With Latitude and Longitude Scales*

Geographic positions may also be plotted with latitude and longitude scales (*C* in fig. 91). These are similar in appearance to a triangular engineer scale, each containing one scale for the plotting of latitude and five scales for the plotting of longitude at various latitudes. With these scales a geographic position is plotted by minutes and seconds directly, without recourse to the *dms.* and *dps.*

Each scale covers a distance slightly longer than 1 minute of arc at a scale of 1:10,000 and is divided into 60 main divisions, each division being further subdivided into 5 divisions. It is thus possible to plot 0.2 second of arc directly from the divisions and to interpolate to 0.05 second. By placing the scale slightly at an angle to the meridians or parallels, the two ends of the scale may be made to coincide with the two adjacent meridians or parallels, thus dividing the intervening space into 60 equal parts. When a station is to be plotted, the correct latitude should be marked at a slight distance each side of the station, the two points being connected by a fine straight line. The longitude may be similarly plotted, the correct position being at the intersection of the two lines; or the longitude may be plotted directly on the line of correct latitude. (For further description see **4822**.)

These scales may be used satisfactorily for plotting stations on scales of 1:10,000 and 1:20,000. They are not particularly useful for other scales. Their chief advantage is in plotting on sheets that contain some distortion, and in checking previously plotted positions. Tests in the Washington Office indicate that geographic positions can be plotted with these scales with approximately the same accuracy as is attained by the use of a beam compass or dividers, and can be scaled or checked with considerably greater speed by one accustomed to their use.

### *7413. Plotting by Transfer*

The stations located by topography are usually placed on the smooth sheet by transfer from the topographic sheet. Ordinarily the topographic survey has immediately preceded a hydrographic survey and its scale has been determined by the desired scale of the hydrographic survey. In such cases, the scales are identical and, if there is no distortion in either sheet, the most expeditious method of transferring the positions of the signals to the smooth sheet is by tracing paper. Tracing cloth should not be used for this purpose since it is subject to larger dimensional changes than the paper.

The tracing paper is securely fastened over the topographic sheet and a needle, or other fine point, is used to prick the exact positions of the topographic stations and the adjacent projection intersections through the paper; the shoreline and topography are usually transferred at the same time (see **7561**). The stations and the intersections are temporarily identified by symbols or otherwise in pencil. The tracing paper is then superposed on the smooth sheet with the corresponding projection-line intersections in coincidence, and the positions of the topographic stations are pricked through the holes in the tracing paper into the smooth sheet, and temporarily marked in pencil.

If there is distortion in one or both of the sheets, the projection intersections will not all coincide. In such a case the tracing paper must be adjusted for each quadrilateral so that the difference between the two projections is proportioned for each station plotted. Sometimes the tracing has to be shifted several times, as where stations are located in different parts of the quadrilateral. Even if there is no apparent difference between the two projections the coincidence of the adjacent intersections should be verified before the stations are pricked through.

Where shoreline and other topographic detail are also to be transferred, it may be found more expeditious to prick on blank tracing paper the projection intersections of the sheet *to* which the transfer is to be made. These pricked intersections are then adjusted, quadrilateral by quadrilateral, to the topographic survey *from* which the detail is traced. This eliminates the awkwardness of having to shift constantly both the tracing and the transfer paper when making the final transfer to the smooth sheet (see **7561**).

### *7414. With Proportional Dividers*

Control stations may be transferred from one sheet to another by proportional dividers, but this method should be used only where the transfer is from a comparatively large-scale survey to a comparatively small-scale one. The principle of the proportional dividers is explained in **4812**. In using them for the transfer of stations, the scale setting of the dividers must be used only for a preliminary adjustment. Before actual use, a final setting must be made by trial and error on the two projections. In most cases, one setting will suffice for both latitude and longitude measurements; but this should be verified and if necessary a different setting used. Control stations transferred by this method should be plotted as explained in the second and third paragraphs of **7411**.

### *7415. Plotting by Cuts*

*Cuts* are sextant angles, usually taken from a survey vessel, between an object whose position is known and an object whose position is to be determined. The position of the observer is located by two sextant angles. Two or more such cuts taken from different positions determine the position of the unknown object. Cuts may also be taken from previously located shore stations. Cuts are recorded in the various Sounding Records and indexed on page 2 of volume No. 1 (see **248**).

To plot a control station from sextant cuts, the position of the observer is first carefully plotted, if not at a previously determined station, using a metal protractor whose adjustment has been previously checked (see **762**). The third angle or cut is then set on the protractor and with the center placed directly over the observer's position and one arm passing through the known station, the angle to the new station is plotted by a short line drawn along the edge of the protractor arm with a hard chisel-edged pencil (see **724**). This must be temporarily identified by the name of the new station in pencil. All other cuts to this same station are plotted in a similar manner from the respective locations from which they were taken. If the observing has been carefully done and based on control precisely located, and the sheet is free from distortion, all of the cuts should intersect at one point, which is the location of the station. It rarely happens that this is the case, and a position must be adopted which will most nearly fall on all of the plotted cuts, taking into consideration their respective probable accuracies. The penciled cuts must not be erased from the smooth sheet until after the verification of the survey in the Washington Office.

### *7416. Stations Located by Three-Point Fixes*

Control stations are sometimes located by three-point fixes at the station. In such cases their positions may be plotted on the smooth sheet with the three-arm protractor (see **4534**) verifying the plotting with the check angle, if taken. If there is distortion in the sheet or if stations observed are considerable distances away, the position should be computed on Form 655 (see **2431**) and plotted on the smooth sheet by the *dm.* and *dp.* method.

## 742. PLOTTING THE FLOATING CONTROL

The floating control which may be used to control a hydrographic survey usually consists of survey buoys or sono-radio buoys, and occasionally small marker buoys. There are various methods of determining the positions of such buoys depending upon the availability of shore signals, the distance offshore, the character of the area surveyed, etc. These methods can be grouped generally as follows: (*a*) sextant locations either by three-point fixes at the buoys or by cuts from the vessel; (*b*) directions from shore stations; (*c*) sun azimuths from the vessel to shore stations; (*d*) sun azimuths and distances; (*e*) astronomic observations; (*f*) by reference to submarine relief; and (*g*) various combinations of these.

A complete discussion of these methods as well as the methods to be used in determining the geographic positions of the buoys is contained in section **25**. In determining the geographic positions for smooth-sheet plotting, the plotter should follow the method recommended for the particular case involved. The following item deals only with certain general aspects of the problem.

### *7421. Determining Positions of Floating Control*

The positions of the floating control are ordinarily known prior to the construction of the smooth sheet, since they must be known in order to execute the field work. There are two general methods of obtaining these positions, (*a*) by computation and

(*b*) by graphic plotting on an aluminum sheet. In both methods the geographic positions of the buoys, and consequently their *dms.* and *dps.* are obtained; hence positions of the buoys are plotted on the smooth sheet in the same manner that shore stations are plotted by *dms.* and *dps.* (see **7411**). Graphic methods usually furnish the required accuracy of position for buoy-control surveys, provided accurate methods are used and care is exercised in the plotting; but it is frequently desirable and easier to compute the positions.

*a. By computation.*—Positions of buoys are determined by computation generally when it is not practicable to plot the observed data on the smooth sheet, as when the sheet is distorted or the scale is too small or the stations observed on are too far distant.

*b. By graphic plotting.*—Graphic plotting should generally be resorted to when the data can be plotted on an aluminum sheet, or where the computations are too involved as in the case of cuts obtained from a vessel whose position is determined by a three-point fix. (See **2552** for detailed description of latter method.) Graphic plotting should also be used where buoys are located by taut-wire distances or by subaqueous sound ranging or by reference to submarine relief.

Where a number of buoys have been located and plotted by three-point fixes, it may be desirable to compute the positions of selected ones to verify the accuracy of the graphic plotting.

In graphic plotting, an accurately adjusted metal protractor should always be used and the work should be done with the utmost care and precision. Usually the buoys are in such locations that the angles of the three-point fix are relatively small, which tends to magnify plotting inaccuracies.

### 743. STATION SYMBOLS

Each station used for the control of the hydrography shall be identified on the smooth sheet by its appropriate symbol and name, both inked in the color specified (see fig. 169). The actual station point is a fine needle hole, the edges of which are blackened by rotating a sharp hard pencil point in the hole to facilitate its use in plotting the hydrography. Ink should never be used for this purpose (disregard fig. 169 in this respect). The symbols and colors shall be according to the following scheme:

(*a*) Triangulation and traverse stations shall be identified by red equilateral triangles, 4.5 mm on a side (fig. 153), symmetrically placed around the station point with the base of the triangle normal to the meridian and the apex north.

(*b*) Topographic stations shall be identified by red circles 3 mm in diameter, symmetrically located around the station point. Stations on air photographic surveys which have been located by the radial plot for the use of the hydrographic party, are classed as topographic stations. Stations to supplement those located by the radial plot, and which are located by the hydrographic party by approved methods, shall also be classified as topographic stations (see **2393**).

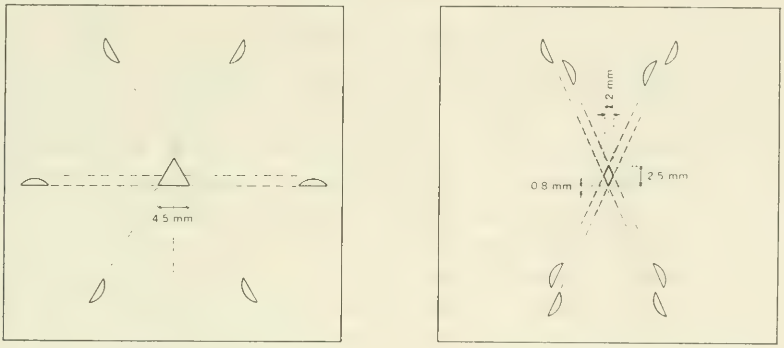
(*c*) Hydrographic stations (stations located by sextant or other means, see section **24**) shall be identified by blue circles 3 mm in diameter symmetrically located around the station point. The positions of ordinary survey buoys are to be identified by the symbol for hydrographic stations.

(*d*) Stations which have been spotted by the hydrographic party from the details of the photographs or the air photographic survey (see **2394**), shall be identified by green circles 3 mm in diameter, symmetrically placed around the station point.

(*e*) R.A.R. stations shall be identified by a double concentric circle, the inner 3 mm in diameter in blue ink, and the outer 5 mm in diameter in a distinctive color corresponding to the distance arcs drawn from it (see **7637**).

The symbols for topographic and hydrographic stations are easily made and centered by the use of the drop-bow pen (see **4841**). There is some difficulty, however,

in making the triangulation station symbol neatly and symmetrically around the station point. There are several methods of doing this. One method is to draw a faint pencil circle 2.6 mm in diameter, and with a straightedge and an equilateral triangle draw the sides of the symbol tangent to the circumference of the penciled circle.




Triangulation station

Buoy

FIGURE 153.—Templates for triangulation station and buoy symbols.

Another method is by means of a celluloid template cut to the correct size (see fig. 153). The perpendicular etched lines are used in centering the symbol and in orienting it with reference to the projection lines. The small holes on the extensions of the triangle sides are used to draw pencil lines as guides for drawing the symbol in ink after removal of the template. Inking inside the template cannot be neatly done and should not be attempted. (See also **4834** and fig. 96.)

## 744. STATION NAMES

All of the station names shall be inked on the smooth sheet in vertical letters with an over-all height of the upper case letters not to exceed 3 mm, and a thickness of ink line not to exceed 0.5 mm. Slanting letters shall not be used for any station names. Under this heading instructions are given only for station names (see **215** and **3245**). Instructions for geographic names are given in **787**. Instructions for names of aids to navigation are given in **7843**, and instructions relative to miscellaneous notes are given in **781** and **7825**. The names of triangulation and topographic stations shall be in red ink, names of hydrographic stations in blue ink, and names of stations spotted from the air photographic detail shall be in green ink. (See figs. 169 and 171.)

Where only a part of the triangulation station name is used in the hydrographic survey, this part shall be emphasized by underlining it in red ink. Where an entirely different name, arbitrarily selected, is given to a triangulation station, for use in the hydrographic survey, the arbitrary name shall be inked in blue, followed by the triangulation name in red and in parentheses.

### *7441. Agreement of Names*

The station names on the smooth sheet must agree with those used on the boat sheet, the topographic sheet, and in the Sounding Records. If there is any disagreement between these three sources it must be investigated and corrected, and the name actually used in the Sounding Records placed on the smooth sheet with an appropriate notation in the various records to clarify the original discrepancy.

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Where identical stations are used in the overlapping area of two hydrographic surveys, the station names must be identical. If, inadvertently, a different name is used than appears on the prior survey, both names shall be placed on the smooth sheet, the one actually used in the Sounding Records being followed by the older name in parentheses with an appropriate explanatory note.

### *7442. Size of Lettering*

Unless the draftsman is particularly skilled in lettering, it is preferable that a mechanical lettering set (see **4834**) be used in inking station names on the smooth sheet. The 3 mm maximum height of upper case letters may be obtained by the use of Leroy lettering set template No. 120 with No. 00 pen. Although letters 3 mm in height are to be considered the standard, in congested areas this size is sometimes impracticable and a smaller size must be used.

The most important station names shall be in capital letters; included in this designation are all triangulation station names and the station names of the most prominent signals (i. e., those most frequently used). Station names of all minor signals on a hydrographic sheet (i. e., those used only for sextant fixes in the immediate vicinity) shall be in capitals and lower-case letters.

### *7443. Placement of Station Names*

North shall be considered the top of the smooth sheet and all station names shall be lettered on lines normal to the central meridian. Wherever practicable, names shall be on line with the bottom of the station symbol, and east of and separated from it by a space of one letter (see fig. 169). There should never be any doubt as to the name of a station. Where it is necessary to place the name so far away that doubt may arise as to its reference, a fine inked arrow or leader, in the same color as the name, should be drawn from the name to the symbol. The leader should be broken where it crosses soundings.

Names should never be placed in the water area where it is practicable to avoid it. Where this cannot be avoided, as in some cases of hydrographic stations (particularly survey buoys) or stations on detached rocks, the names must be placed where they will interfere least with the plotted hydrography. The inking of such names must be deferred until after the soundings have been penciled.

The name of a triangulation station must always be followed on the same line (not below) by the year of establishment and the year of recovery, a comma separating the name and the date, and a hyphen separating successive dates.

### *7444. Stations in Water Areas*

Unless it is clear from the topographic information, names of stations offshore from the high-water line must be accompanied by a brief note, or legend, explaining whether the stations are located on permanent features (natural or artificial), or on temporary ones. If the station is on a rock or shoal, the desired information is usually apparent. If it is on a pile or other structure built in the water, or is on a pole placed in the water by the hydrographic party, the note must explain fully the circumstances, so that the cartographer will know whether to chart an obstruction, pile, or other feature at the location. Such notes should be in black ink, as closely adjacent to the station name as practicable, but indubitably referring to it. (See **781**.)

### 745. Verification of the Control

The plotting of the control must be verified by a person other than the one who did the plotting. The verification must consist of the actual replotting of the stations, their placement in the correct quadrilaterals of the projection, and their identification by the correct names.

Only after this has been done, are the symbols and names to be inked.

### 746. Projection and Control Data

The projection and control data shall be given in the lower right-hand corner of the smooth sheet, and rubber Stamp No. 42, Hydrographic Survey, shall be used for this purpose. The center of the stamp should be about 7 inches from the right edge.

Entries should be made in all of the applicable spaces of the stamp. The initials of the persons plotting and verifying each of the items listed should be entered, together with the dates. It is important that the verification information be given, otherwise unnecessary duplication results, since the Office cannot assume a field verification unless evidence of this appears on the survey sheet. If an item in the stamp is not applicable to a particular survey, as where no hydrographic stations are on the sheet, an explanatory entry should be made, such as "none" opposite "Hydro. Sta."

The registry number of the survey shall be given if known, as well as the field number (see **154**). Opposite the item "Ref. Sta." on the stamp, the name and date of establishment of some one triangulation station on the sheet, should be given. The latitude and longitude with seconds in meters shall be given immediately below. Whether the position has been adjusted or not shall be indicated by ruling out the inapplicable abbreviation following the data, if this is known.

All of the projection and control data shall be shown in black ink. A facsimile of Stamp No. 42 with the necessary data entered is shown in figure 154.

| | | |
|---|---|---|
| **No. 42 HYDROGRAPHIC SURVEY** | | |
| **Field No.** Oc-8341 | **Reg. No.** H-6671 | |
| **Scale 1:** 80,000 | **Plotted.:** | **Verified** |
| Projection | H.J.C. | F.C.M. |
| Tri. Sta. | H.J.C. | F.C.M. |
| Topo. Sta. | H.J.C. | F.C.M. |
| Hydro. Sta. | H.J.C. | F.C.M. |
| Datum NORTH AMERICAN 1927 | | |
| Ref. Sta. BALD HEAD, 1854 | | |
| Lat. 43° 42' 685.8 m. | **Adj.** | |
| Long. 69° 51' 375.7 m. | ~~**Unadj.**~~ | |

FIGURE 154.—Projection and control data for smooth sheet.

## 75. TRANSFER OF THE TOPOGRAPHY

The hydrographic smooth sheet, as finally registered, is not the authority for the topography, which is surveyed on a separate sheet. Where the topography is surveyed by planetable, it is usually done in the same season, immediately preceding the hydrographic survey and under the direction of the same Chief of Party. In the case of air photographic surveys, however, the photographs may have been taken several years earlier and the planimetric maps may have been completed some time before the hydrographic survey. Infrequently there is no contemporary topographic survey; that is, no survey accomplished during the same season or in a season immediately preceding the hydrographic survey, which is considered to be a part of the same project.

The Chief of Party shall have the hydrographic party verify, and revise if necessary, the high-water line and all topographic details offshore therefrom, which are

derived from the topographic survey, so that they are correct and in agreement with data originating with the hydrographic survey (see **381**).

In order that the hydrographic survey may present a complete graphic record of the area, all topographic details within the limits of the hydrography and adjacent to it, including the high-water line, must be shown on the smooth sheet except as noted in **751**.

The transfer of the topography must be made with the utmost care so that there is no appreciable inaccuracy in position. Photographic copies of the hydrographic surveys are frequently furnished to the public and to governmental agencies, and it is

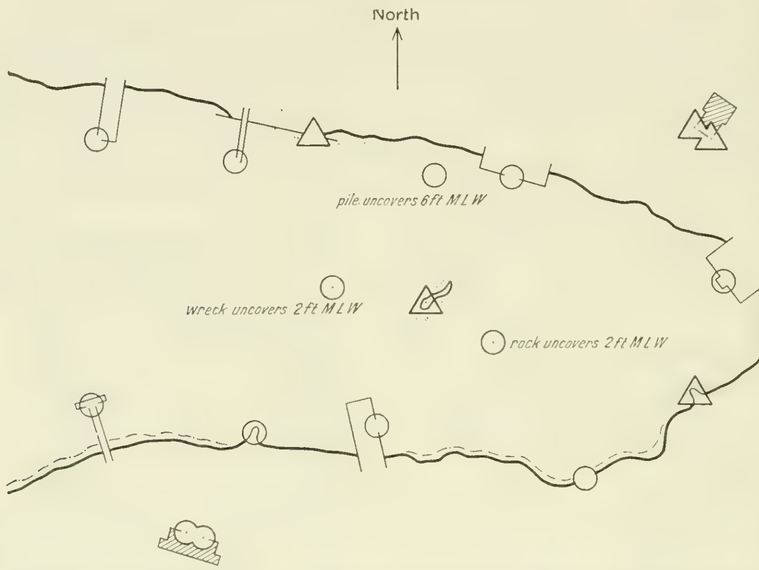


FIGURE 155.—Shoreline shown on smooth sheet without obscuring positions of control stations.

naturally assumed by many of these that the topographic details shown thereon are correct.

When the topography is transferred, the high-water line and all offshore details are transferred at the same time *in pencil*, but are inked only as specified in **752** to **755** inclusive (see also table 28). Topographic detail must never obscure the centers of control stations. Only important detail should be shown inside the station symbol, but in no case shall the shoreline be drawn through the station point. Examples to be followed are illustrated in figure 155.

Topographic details inshore from the high-water line shall be omitted from the smooth sheet, except where stations are on or near buildings (see **7844**).

## 751. Omission of Topography

The field plotter may omit all or part of the topography from the smooth sheet in the following cases:

(*a*) Where there is no contemporary topographic survey. After the hydrographic survey has been reviewed in the Washington Office, a decision will be made as to whether any topography is to be shown thereon.

(*b*) Where the topographic and hydrographic surveys are on different scales and the transfer presents difficulties. In such cases the topography will be added to the sheet at a later date in the Washington Office.

(*c*) From an offshore survey (one where another survey exists or is contemplated between it and the shore). If the survey is on the same scale as the topographic survey, the high-water line only should be transferred but not the topographic detail adjacent to the shore.

(*d*) From wire-drag smooth sheets where the drag limits are not very close to the shoreline. Where the shoreline is shown, it is not necessary to transfer all the rocky detail adjacent thereto. It is usually sufficient to show only such off-lying rocks and reefs as were factors in delimiting the inshore extent of the dragged area.

## 752. The Shoreline

The shoreline which is shown on the topographic survey and likewise on the smooth sheet, and on the charts published by the Coast and Geodetic Survey, is a *mean high-water line,* except in marsh and mangrove areas. In the latter cases the shoreline is the visible edge of the marsh or mangrove, because this is the line which appears to the mariner as the shoreline.

After transfer of the topography, the mean high-water line should be inked at once, except in those areas where the boat sheet dislcoses a possible conflict between the shoreline as located by the topographic survey, and the hydrography. In such cases the shoreline shall be left in pencil until the soundings have been plotted and a study made of the results. All details offshore from the high-water line must also be left in pencil pending the plotting of the hydrography.

The mean high-water line on fast solid land shall be shown on the smooth sheet by a firm continuous solid black line about 0.4 mm thick. The shoreline of marsh, swamp, and mangrove areas shall be shown by a fine solid black line about 0.2 mm thick. (See **962**.) The outlines of small details of waterfront areas, such as small piers and bulkheads, shall be shown by moderately fine lines, somewhat finer than those used for the mean high-water line on fast land, in order that the small details of pier lines and pier corners may not be obliterated. (See fig. 169.)

## 753. Revisions by Hydrographic Party

The hydrographic party is responsible for the correctness of the topographic detail falling within the limits of the hydrographic survey, including the high-water line and waterfront details if the survey is carried close thereto. Where the topographic survey was not made in the same season as the hydrographic survey and under the direction of the same Chief of Party (see **381**), revisions or corrections thereto shall be shown on the smooth sheet, according to the following instructions:

(*a*) Where the revised shoreline or topography has been determined by standard topographic methods or methods resulting in an equal accuracy, it shall be inked in a solid red line.

(*b*) Where the revised data are only sketched by careful estimation or are based on sextant fixes, or sextant cuts, they shall be inked in broken red lines. Where the shoreline has been sketched by the method described in **3812**, it shall be left in a broken pencil line by the field party, to be inked in the Washington Office in a broken black line when, at the time of review, no accurate survey is known to be contemplated.

(*c*) The thickness of the inked lines shall be equal to those prescribed in **752** (i. e., 0.4 mm for the shoreline of solid ground and 0.2 mm for the visible edge of marsh or mangrove areas).

(*d*) Appropriate notes shall be made both on the smooth sheet and in the Descriptive Report explaining the discrepancies and the methods used in determining the positions of the revised data.

The red color will distinguish immediately between shoreline and topography which have originated with other sheets, and the revised data for which the smooth sheet and the hydrographic party are the authority (see fig. 169).

### 754. The Low-Water Line

The low-water line shown on the planetable survey is usually not a surveyed line. It has ordinarily been sketched by the topographer and is furnished as a guide to the hydrographer during his hydrographic survey. Occasionally, however, where the topographer is in a locality at low tide, he may actually delineate the low-water line by rod readings.

The low-water line is the curve of zero depth and its best delineation for hydrographic purposes results from soundings obtained in its vicinity. Since such soundings are subject to possible modification in the Washington Office, caused by changes in the tide reducers or for other reasons, the low-water line shall be left in pencil on the smooth sheet by the field party, to be subsequently inked in the Office when the survey is verified. Where minus soundings are plotted, care must be taken to see that the curve is correctly shown relative to them (see **7715**).

After the soundings have been penciled on the smooth sheet, the complete low-water line shall be shown thereon *in pencil* in accordance with the following preferences, using the same symbols as are prescribed for its inking (see fig. 169):

(*a*) The zero depth curve as determined by the reduced soundings in areas where the hydrographic survey has extended over the low-water line during periods of high water—to be eventually inked as a continuous yellow line.

(*b*) Those parts of the low-water line that were rodded in by the topographer at low tide—to be eventually inked as a black line of alternate dashes and dots.

(*c*) Those parts of the low-water line which can be reasonably well determined from notes in the Sounding Records and sketches on the boat sheet made by the hydrographer at the time of the hydrographic survey—to be eventually inked as a yellow dash line.

(*d*) In cases not covered by any of the preceding three classes the low-water line shall be taken from the best available source, usually that sketched on the topographic survey—to be eventually inked as a black dotted line.

Occasionally it may be desirable to delineate the low-water line by symbols, such as for rocky ledges or coral reefs. In such cases the offshore edge of the symbols shall be considered the low-water line.

The low-water line derived from an air photographic survey shall be considered to be in class (*d*), unless there is a positive statement in the Descriptive Report that parts of it were rodded in by planetable, when of course those parts shall be considered in class (*b*). The latter, however, is rarely the case.

### 755. Offshore Detail

Topographic details offshore from the low-water line, such as rocks, reefs, ledges, rocky areas, and shoal areas, except islands or islets of some extent, shall be left in pencil on the smooth sheet until the soundings have been penciled. The hydrographic survey frequently contains data which supplement, and in some cases modify, the topographic survey. Before such details are inked on the sheet, all of the data must be considered and disposition made as to character, location, and elevation in accordance with the rules prescribed in **782**. (See also **7862**.)

It is unnecessary to transfer the elevations of bare rocks that do not fall within the limits of the hydrography, such as the numerous rocks that are often found close to the high-water line in certain areas.

## 756. Methods of Transfer

There are five methods of transferring topographic detail from one sheet to another depending on the respective scales of the two sheets, the degree of accuracy sought, and the instrument equipment available. These are: (*a*) by tracing paper; (*b*) by projector; (*c*) by pantograph; (*d*) by the method of squares; and (*e*) by the radial-line method. The projector and pantograph are generally not available to field parties nor to Processing Offices and these methods are, therefore, not described in this section. A description of the projector is given in **4854** and of the pantograph in **4853**.

### *7561. Tracing-Paper Method*

Where the topographic and hydrographic surveys are on the same scale, the simplest method of transfer is by means of tracing paper. Tracing cloth must not be used. As explained in **7413** the topographic details are traced at the same time that the topographic control is pricked through, making the adjustments for distortion by small shiftings of the tracing on the topographic sheet. The transfer to the smooth sheet can be accomplished in several ways. The preferred method is to use a letter-size sheet of thin transfer paper, which is prepared in advance by dusting with red offset chalk powder (Kiel), or dry powdered graphite, rubbing it lightly over the surface with a small rag until an even coating is produced. Red is preferable because of its contrast with penciled or inked detail that may be on the smooth sheet. These materials are needed in very small quantities and will be furnished by the Office on request. Vermilion dry pigment should not be used because it is slightly greasy. In an emergency black or red carbon paper can be used.

The actual transfer is made by superposing the tracing on the smooth sheet so that corresponding projection intersections are in exact coincidence. The transfer paper is then placed, coated side down, between the tracing and the smooth sheet and with a stylus or sharp hard pencil the detail on the tracing is gone over. This leaves a sharp outline on the smooth sheet. The transfer paper is moved to an adjoining portion of the sheet and the procedure repeated. It is of the utmost importance that the tracing does not slip during the transfer process. This should be checked as each portion is transferred. The transferred detail is subsequently inked or penciled as explained in **752** to **755** inclusive.

Where a small amount of transfer is involved, the reverse side of the tracing itself may be coated, applying the powdered chalk only in the vicinity of the topographic details. Another method is to smear the underside of the tracing paper with the lead of a soft pencil, using the side of the lead for the purpose. Special care must be taken with the latter method because of the danger of distorting the tracing paper during the rubbing.

In transferring detail by the tracing-paper method excessive pressure must not be used on the tracing, as this will engrave the lines in the smooth sheet. A slight pressure is generally sufficient to ensure a satisfactory impression.

The tracing or tracings used in the transfer shall be forwarded to the Washington Office with the boat sheet (see **8351**).

### *7562. Method of Squares*

This method is not sufficiently accurate for the transfer of topographic detail to the smooth sheet, but may be used to transfer the shoreline to the boat sheet or in other cases.

In the method of squares (fig. 156), common points on the two surveys are selected—usually intersections of meridians and parallels. Referred to these common points, sets of corresponding squares or rectangles are constructed lightly in pencil, which are identical when referred to the actual

ground detail, but differ in size on the two sheets. Every fifth line should be accentuated to facilitate identification. The detail may then be transferred from one sheet to the other by reference to the positions within these small squares.

In order to obtain any reasonable accuracy, the squares on the smaller scale should be formed by lines not more than one-eighth inch apart. When these squares are correctly drawn, they may be termed *corresponding squares* because each square corresponds to its respective square in terms of the ground area.


FIGURE 156.—Reduction of topography by method of squares.

If it is desired to avoid marking up the source sheet, the squares may be drawn on tracing paper and laid over the detail to be transferred. The procedure is then the same as above.

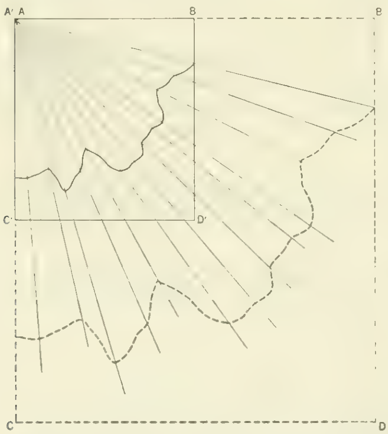


FIGURE 157.—Reduction of topography by radial-line method.

### *7563. Radial-Line Method*

Like the method of squares, this method (fig. 157) should not be used for transferring topographic detail to the smooth sheet. It is of most value where only an approximate accuracy is needed and the detail consists only of the high-water line. It is faster than the method of squares. To use the method, a point common to the two surveys is selected from which radial lines can be drawn to intersect the general trend of the shoreline at not too acute an angle.

In practice, tracing paper is placed over the sheet with the source material, and from the selected point radial lines are drawn to intersect the shoreline at all salient points and at enough intermediate points to permit fairly accurate sketching of the detail. In the simplest case, where it is desired to transfer to a scale twice as large or half as large as the original, it is merely necessary to use dividers to double or halve the radial distances from the common point to the intersections with the shoreline and plot the new distances along the same lines. Subsequently the intervening

shoreline is sketched in pencil by eye through the new points so that it corresponds to the original. The shoreline at the new scale may then be transferred by one of the methods described in **7561**. This same method can, of course, be used to increase or decrease the scale in any proportion by the use of proportional dividers.

### 757. Verification of Transfer

The transfer of all the topographic details must be verified by a person other than the one doing the original work. A statement that this has been done shall be included in the Descriptive Report, accompanying the statement giving the source of the topographic detail (see **842*G***). If the detail is to be inked in the field (see **792**), the verification should be made after the inking.

## 76. PLOTTING THE POSITIONS

As explained in **332**, there are at present various methods or combinations of methods by which the hydrography is controlled, depending on the conditions under which the operations are carried on. The most common of these are: (*a*) The three-point fix method in which the position of the vessel is determined by measuring simultaneously the two angles between three control stations (see **333**); and (*b*) the Radio Acoustic Ranging method in which distances from the vessel to two or more hydrophone stations, whose positions are known, are obtained by subaqueous means (see **612** and **681**).

In this section is given the general procedure for plotting all positions as well as the detailed procedure for the above two methods. In addition the methods for plotting astronomic positions and dead reckoning are described. The procedure for plotting positions determined by special methods will be apparent from the description of those methods (see **3323**).

Prior to plotting the positions, and at least once a month during the progress of the plotting, the protractor must be tested and the metal protractor adjusted, if necessary (see **4533**).

The positions on sounding lines are usually plotted in the order in which they were taken; that is, the smooth plotter begins with position 1 of "*A*" day and plots all of the positions on the smooth sheet in the order in which the work was actually executed in the field. This is not obligatory, of course, and in fact it may be preferable to plot the positions in critical areas first, especially if plotting is done while field work is still in progress, in order to give immediate evidence whether additional work is required in the area.

In plotting the positions, use should be made of the entries in the Sounding Records at the beginning of each day's work, giving the approximate latitude and longitude of the first position. This is given to facilitate the plotter in locating quickly that portion of the smooth sheet on which the position falls. Similar information is given at the beginning of any line starting in a new area.

In plotting the smooth sheet, a certain systematic procedure is necessary to permit the smooth plotter to attain speed and still retain accuracy in his work. As the plotting proceeds, he soon learns to sense where there is some deficiency in the recorded data. It is imperative for best results that the person plotting the smooth sheet be familiar with the methods by which the field work was done. If the plotter has not actually been engaged in similar work, he should study the Hydrographic Manual so thoroughly that all phases of the work will be clear to him, and as the plotting proceeds he will be able to visualize the progress of the vessel during the work.

During the plotting of the positions on the smooth sheet, continued reference should be made to the notes in the "Remarks" column of the Sounding Record (see **815**) and to the notes that are kept during the progress of the field work from which the Descriptive Report is subsequently written (see **385**). Quite frequently valuable information will be found in these sources which will guide or influence the plotter during his work. When the plotting of each day's hydrography has been completed, the smooth plotter enters his initials with a colored pencil at the end of the day's entries in the appropriate space in Stamp No. 38, Processing (fig. 183), to indicate his responsibility for the plotting of that day's work.

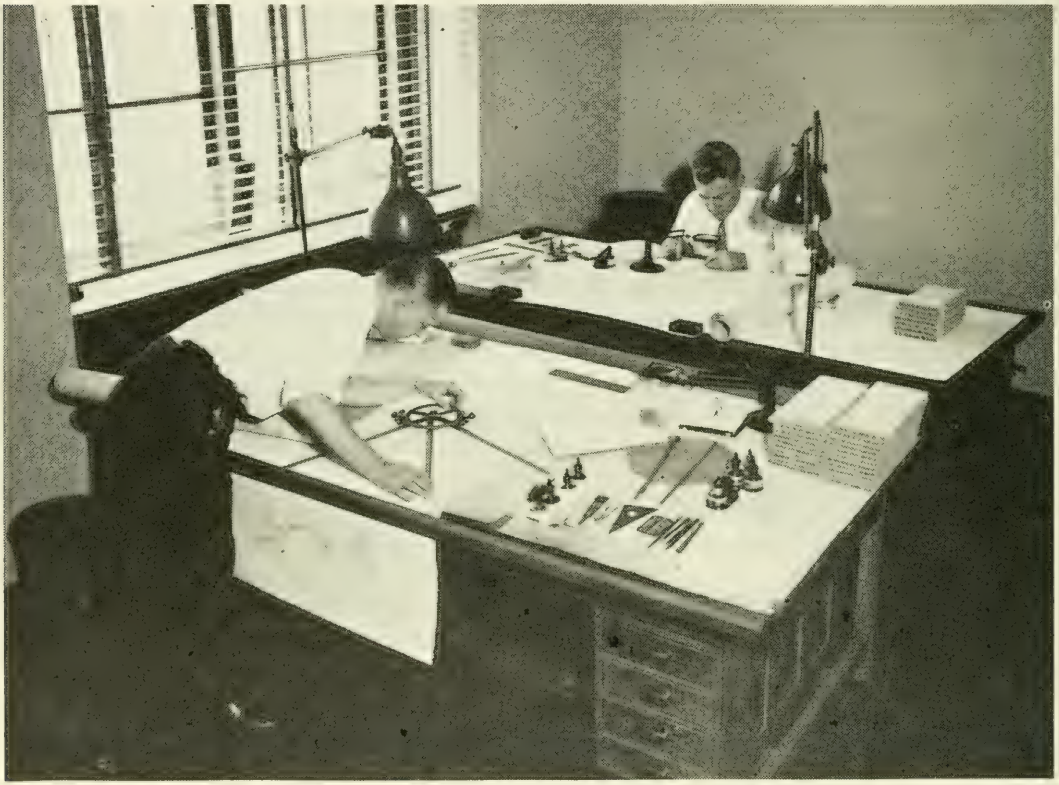

FIGURE 158.—Protracting three-point fixes with three-arm protractor.

## 761. SMOOTH-SHEET COVERS

To protect the surface of the smooth sheet while the protractor is being used, the entire sheet should be covered with a piece of tracing cloth or heavy tracing paper, otherwise the continual sliding of the protractor over the sheet will soil it excessively. A small round hole, about three-eighths inch in diameter, is cut in the cover over each station, exposing the center to permit accurate plotting. The holes should be cut cleanly so that their edges will not fray out and catch the protractor arms. One method of cutting the holes, after they have been marked in pencil, is by the use of a grommet hole cutter. If the cover is difficult to see through, it is desirable to letter each station name on the cover alongside its respective hole. Positions plotted by protractor are pricked through the cover into the smooth sheet.

Thin celluloid may also be used as a protective cover. This material is so transparent that small circular holes at the locations of the signals are unnecessary. The principal objection to celluloid as a protective medium is the difficulty in making temporary notes on it and in identifying the successive positions as they are plotted.

After being correctly placed in position, the cover should be secured by weights or thumbtacks. Since it is necessary to lift the cover frequently, it will be found convenient to secure it along the edge of the sheet farthest from the plotter with a sufficient number of tacks to hold it in position, using only one or two tacks elsewhere.

It is not necessary to lift the protective cover every time a position is plotted. Occasional positions, say every fifth one, may be numbered temporarily on the cover itself. It is customary to plot at least all of the positions on one page of the Sounding Record, or all of the positions on a line, before raising the cover to number the positions on the smooth sheet and to connect them (see **7682**). The smooth sheet should always be covered when not in use.

R.A.R. smooth sheets are difficult to keep clean since the plotting of positions must be done directly on the surface of the sheet. A convenient method of protection is to use two obsolete charts or pieces of wrapping paper folded in the form of envelopes to fit loosely over each end of the smooth sheet, each envelope being held together by Scotch tape. These are supplemented by two pieces of paper folded lengthwise over the sides of the smooth sheet, but with the ends open. The paper should completely cover the smooth sheet when each pair is in its innermost position. The envelopes should fit loosely enough so that they may be slid away from the smooth sheet as desired in order to expose the area being worked on. Several loose sheets of paper or a hand towel should be laid on top of the exposed surface to prevent its being touched by the hands or arms any more than is absolutely necessary.

## 762. Protracting Three-Point Fix Positions

Three-point fix positions are plotted graphically in hydrographic surveying by the use of a protractor. This is usually a three-arm protractor made of either metal or celluloid having a fixed center arm and two movable arms with which the two observed angles can be set. The left angle of the fix is set with the left movable arm and the right angle with the right movable arm. The protractor is then manipulated into a position on the smooth sheet so that the three arms pass precisely through the respective centers of the plotted positions of the stations between which the angles were measured. The intersection of the three arms, which is the center of the graduated circle, then marks the position of the vessel or sounding. (See **4534**.)

### *7621. With Metal Protractor*

Most three-point fix positions are plotted on the smooth sheet with the metal three-arm protractor described in **4531**. The construction of the metal protractor is such that it is inconvenient or impossible to use it in plotting positions which are at short distances from the stations. Neither can it be used with the rapidity or ease with which a celluloid protractor can be used.

Extensions to the arms of a metal protractor are provided for use where the stations observed on are so distant that the regular arms do not reach them. When these extensions are used, extra precaution should be taken in the plotting.

### *7622. With Celluloid Protractor*

The use of the celluloid protractor (**4536**) shall be limited to areas of the smooth sheet where the stations are never more than 10 inches from the positions, the sum of the two angles is not less than 60°, and the smaller of the two angles is not less than 20°. Positions based on stations farther away than 10 inches or based on angles smaller than the above prescribed limits, must be plotted with a metal protractor. Critical positions shall be plotted with a metal protractor, if practicable.

### *7623. Positions Close to Control Stations*

Celluloid protractors of the present model permit plotting three-point fixes which are quite close to the control stations, but because of the opaqueness of the protractor near its center, it sometimes happens that even this cannot be used satisfactorily. In such cases the angles of the three-point fix are plotted on a piece of tracing paper, or on a transparent paper protractor (**4539**), which is then manipulated the same as a three-arm protractor to plot the position.

### *7624. Procedure for Protracting Positions*

The Sounding Record is the official record of the sounding and position data, and the plotter should follow the recorded data strictly, unless it is apparent that an error has been made. Since the system of field work requires that the sounding vessel proceed at as nearly a constant speed as practicable (see **3461**), and since the hydrographer, almost invariably, attempts to run straight lines, the dead-reckoning position of the vessel provides a reasonable check on the recorded position data. The boat sheet provides the best check since the positions thereon were plotted by the officer-in-charge at the time the work was executed, and he was in a position to know where his vessel was at the time a particular position was taken (see **7671**).

Lines of soundings are run systematically, and it is usual for a number of positions to occur on a comparatively straight line (see **314**). The smooth plotter, therefore, usually protracts all of the positions recorded on one page of the Sounding Record, or on one straight sounding line, before comparing them with the boat sheet and connecting them with penciled lines. When the plotter has assured himself that the positions of the series have been correctly protracted, a checkmark in colored pencil must be placed in the Sounding Record alongside each position number. A pencil of identical color should be used by the smooth plotter throughout his work, in making entries and corrections in the Sounding Records.

As the protracting progresses, the notations in the "Remarks" column should be noted in order that due attention may be paid to any remark which may affect the smooth plotting, and for information regarding features to which cuts were taken or which were otherwise located during the progress of the survey. As each such item is applied to the smooth sheet, this should be indicated by placing a checkmark after it in the Sounding Record.

It is usual to protract all of the positions on the smooth sheet before the soundings are penciled, including the detached positions and all the cuts and other data that need to be located on the smooth sheet. When the protracting has been completed, the smooth sheet should contain all position information and, in general, it should not be necessary to use the protractor during the subsequent plotting of the soundings, except for occasional verification of a position.

A. ERRORS IN RECORDED DATA

Although every effort is made to have all data recorded with the strictest accuracy, the smooth plotter must keep constantly in mind the fact that in many cases the hydrography is performed under circumstances conducive to errors in recording. The recorder is frequently working under continuous pressure, and since the hydrography proceeds at a constant rate and it is his duty to record all phases of it, he may fail to correct known errors, or question suspected data. Launch hydrography is particularly susceptible to recorded errors. Hydrographic launches are often propelled by gasoline engines in which the noise level is quite high. Angles and station names are being called by the observers, soundings are being called by the leadsman, and orders are being given, all in a loud voice, and the recorder is supposed to make an accurate record of all of these at the time they occur.

As the smooth plotter becomes experienced, he will learn the kinds of errors which are most likely to occur in the recorded position data. The following list is not intended to be complete, but will serve as a guide to an inexperienced smooth plotter:

(1) One or more station names may be incorrect—such errors are likely to occur where station names have similar sounds.

(2) The station names are correct, but two or more of them have been transposed.

(3) The right angle and left angle may be reversed.

(4) The degrees and minutes of an angle may be reversed.

(5) The observer may have read his sextant wrong, the most frequent errors being 10°, 30′, 1°, and 20°, in that order.

(6) The recorder may have misunderstood the angle, when called out, as for example, when 15 is mistaken for 50, 7 for 11, and vice versa.

(7) The recorded data appear complete, but actually the right and left angles were not observed to a common center object.

Corrections to recorded data should be made according to **7741** and figure 164.

### *7625. Protracting Inadequate Fixes*

It frequently happens in three-point fix hydrography that the position data obtained are inadequate for plotting the positions by the conventional three-point method. It is then necessary to use special methods of plotting, or the data must be supplemented by other information before the position can be plotted. Such cases occur, (*a*) where only one angle has been observed, (*b*) where the two angles are not observed on a common center object, (*c*) where the three-point fix is weak, and (*d*) where the position is located by estimation.

In (*a*), the procedure is first to plot the locus of the single angle. This is accomplished by setting the angle on the protractor and placing the center near where the position is likely to be. The two arms are then made to pass through the two stations involved. The center of the protractor will then be a point on the locus of the angle. Several such points are plotted in the vicinity of the position sought and a short pencil arc is drawn through them. The exact position of the vessel is then determined by the use of the dead reckoning in conjunction with the plotted locus. If the locus is nearly perpendicular to the course, the next following position on the line should be protracted and connected with the previous position by the dead reckoning. The intersection of the dead-reckoning track and the locus will then give the position. Where the locus is nearly parallel to the course, a strong determination of the direction of the sounding line is obtained, but the position must be determined on a basis of proportional time between the preceding and following positions, assuming there has been no change in speed. Thus, if positions 5*A*, 6*A*, and 7*A* were taken at 9:04, 9:07, and 9:11 respectively, then position 6*A* would be plotted at three-sevenths the distance between 5*A* and 7*A*, on the locus of the observed angle.

Wherever the locus of an angle is to be plotted, this can be done directly on the smooth sheet, using the protractor centerpiece with a hole in it. Only the final position will then be pricked on the sheet. Care must be taken, of course, to see that the underside of the protractor is clean.

In (*b*), which usually occurs through a misunderstanding or error, the position is determined by plotting separately the locus of each angle, the correct position being at the intersection of the two arcs, assuming that they do not intersect at too acute an angle.

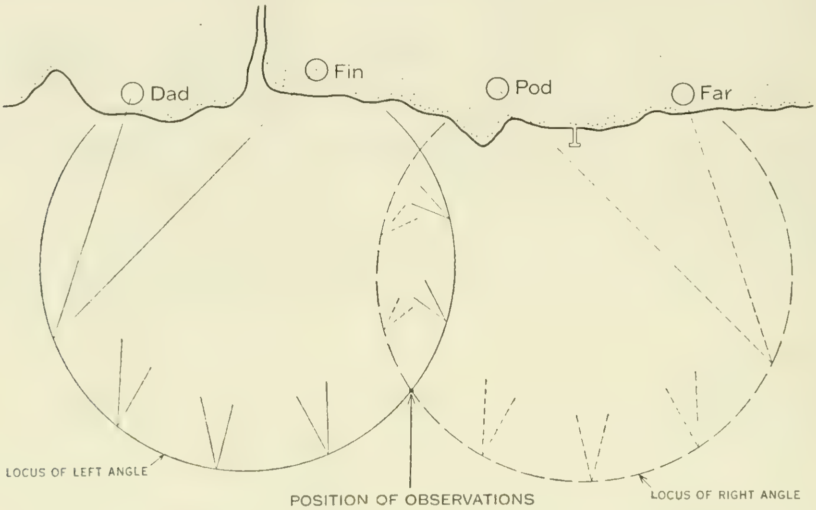


FIGURE 159.—Sextant fix plotted by intersection of loci. No common center object.

In (*c*), the recorded data may be complete, but the fix is weak, giving an inadequate determination of the position (see **3332**). There are two types of such fixes. In one type, the fix can be plotted in one position but the result is erroneous because of the weakness of the fix in conjunction with other factors. In the other type, known as a *swinger* or *revolver*, the fix can be plotted in any one of several positions. In either type, the recorded data must be supplemented by the dead reckoning in order to determine the most probable position. In the first case it is usually necessary to disregard that part of the recorded data which has resulted in the erroneous position, while in the second case all of the recorded data may usually be used to plot a locus of the position.

In (*d*), it is generally not possible to obtain a three-point fix, and other data are usually recorded by the hydrographer for plotting the position, such as an estimated distance from the high-water line, or an estimated distance and direction from a control station. All such data should be plotted and used in conjunction with the dead reckoning in order to arrive at the most probable positions, bearing in mind that the distances are not measured distances, and that the general tendency is to underestimate distances over the water from a stationary position. (See also **335**.)

## 763. PLOTTING R.A.R. POSITIONS

Radio Acoustic Ranging (R.A.R.) is a comparatively new method of control for hydrographic surveys. Notable changes have been made in recent years in the design of the equipment and in the field methods. These are described in detail in chapter 6. Likewise, improvements have been made in the methods and procedure of plotting the smooth sheet. It is expected that these will continue, but at the present time the methods described herein are considered the most satisfactory and shall be used until other methods are proved preferable.

R.A.R. positions are determined by the intersection of distance arcs whose centers are the R.A.R. stations from which the bomb returns were received. Like the distance circles described in **7341** these arcs are plotted in units of time. Because of uncertainties inherent in the R.A.R. method, due principally to the lack of complete knowledge of

the path of the transmitted sound wave, other data obtained during the progress of such a survey must be appraised with the acoustic distances, and the most probable positions adopted. Such supplemental data are sextant angles, bearings, and dead reckoning.

To avoid confusion, too many positions should not be plotted at any one time before they have been analyzed and accepted (see **7637**). In areas of systematic sounding lines not complicated by crosslines, or development, three or four lines may usually be plotted at one time, but in areas where previous lines have been plotted only a comparatively few positions should be plotted before analysis.

Numerous pencil notes are necessary to keep track of position numbers and other data. These must be placed directly on the smooth sheet, since this type of plotting is done without a sheet cover (see **761**). A soft pencil should be used so that the marks may be easily and completely erased.

### *7631. Plotting the Distance Arcs*

Before plotting is begun a small circular piece of heavy celluloid should be fastened over each R.A.R. station to protect the center from wear due to repeated use of the beam compass. The best adhesive is nonvulcanizing rubber cement, thinned by an approximately equal amount of benzol or, as a substitute, benzine. The underside of the celluloid and the respective area on the smooth sheet are covered with a thin coat of cement and allowed to dry until sticky, after which the celluloid is pressed into place. Care should be taken to prick the point in the celluloid directly over the station hole. These protective celluloid pieces should not be confused with those described in **7341** for plotting the distance circles, which are fastened temporarily to the sheet.

All R. A. R. positions must be plotted by means of their distance arcs so that a study can be made of all the factors influencing the final positions. The distance arcs are plotted directly from the data in the Bomb Record (**8311**), in which the measured time intervals have been reduced to the plotting velocity of 1,460 meters per second (see **7341**). The radii of the arcs are found on the smooth sheet by applying short increments or decrements of time to the plotted distance circles. Thus, the plotting radius for a 16.83-second time interval would be obtained by plotting the increment 1.83 seconds from the 15-second distance circle. To plot these increments or decrements on the sheet, three methods are available:

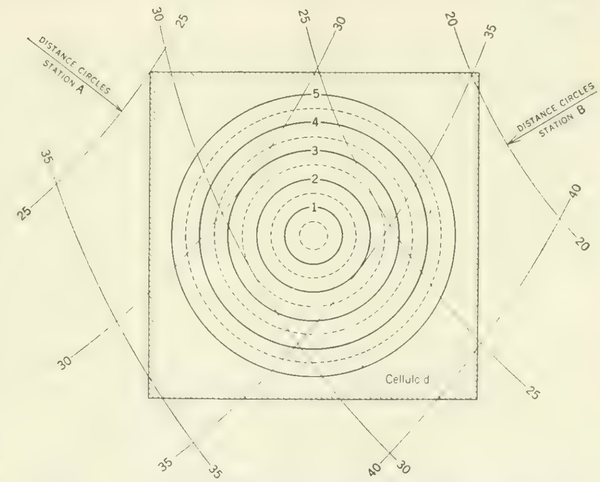


FIGURE 160.—Plotting R.A.R. positions with Odessey protractor. (Position illustrated is 33 seconds distant from station *A* and 27.5 seconds distant from station *B*.)

*a. With Odessey R.A.R. protractor.*—This device, the construction of which is described in **4537**, consists of closely spaced concentric circles on a piece of transparent celluloid, the circles being spaced according to the plotting velocity, 1,460 meters per second, at the scale of the survey. When the device is placed on the sheet so that the circle corresponding to the time increment or decrement is tangent to

the proper distance circle, the center of the device will be a point on the distance arc required. The intersection of the two distance arcs can be plotted in the same manner by making the appropriate concentric circles tangent to the two distance circles involved. The center is then a point on both distance arcs. There is no limit to the number of distance arcs that can be drawn with this device at any one position, although only two distance arcs can be used simultaneously. It is especially well suited for verification work.

*b. With dividers and scale.*—In this method a special scale is used, similar to a metric scale, constructed for the plotting velocity of 1,460 meters per second at the scale of the survey. The increments or decrements are measured with dividers. One point of the dividers is set on the distance circle and, with the aid of a large celluloid triangle alined toward the station, the desired point is pricked along the alined edge. This method is slow because the increments or decrements must be plotted in an exact radial direction from the respective stations.

*c. With R.A.R. plotting scale.*—A long rule similar to an engineer scale is used, with scales graduated in seconds for the plotting velocity of 1,460 meters per second at various survey scales (see **4828**). The rule is long enough to be alined with the station by eye, the desired point being pricked directly along the edge of the graduated scale. If such a scale is not available a substitute can be made on a long narrow piece of celluloid graduated in seconds, with 1 or 2 seconds at one end divided into tenths of seconds, the hundredths being estimated.

After the points for the distance arcs have been pricked on the smooth sheet, short pencil arcs are drawn through them with a beam compass set at the approximate plotted positions of the respective stations. These pencil lines should be short, just long enough to ensure their intersection with the sounding line. For drawing distance arcs of various radii, it is convenient to use two sets of beam compasses, one with a long beam and the other with a short beam, to avoid having to shift the fixtures an excessive amount.

Where two R.A.R. stations comparatively close to one another have been used, distance circles are drawn from only one (see **7341**). To plot an arc from the station for which no circles have been drawn, the increment or decrement is measured from the distance circle plotted on the sheet. The total distance from this pricked point to the true center of the distance circles is set on the beam compass, but the distance arc must be drawn from the R.A.R. station from which the bomb return was received. In this case the point of the beam compass must be centered exactly at each station.

### *7632. Plotting the Sextant Angles*

After the distance arcs have been plotted the sextant angles are plotted. Sextant positions can generally be plotted with a celluloid protractor since they are usually not far from the buoy stations. Single angles are often obtained at R.A.R. positions and the loci of these angles should be plotted, since the locus of each angle so obtained is in effect another distance arc which must be considered in the determination of the final position (see **7635**).

### *7633. Plotting the Bearings*

Bearings may be plotted by several methods. Parallel rulers may be used, but their undersurface should be covered with paper so that the metal will not soil the sheet. An inconvenience in their use is that the pieces of celluloid over the stations are frequently detached by the rulers. The best method of plotting bearings, which is sufficiently accurate, is by using the circular no-arm protractor (**4539**). When this instrument is used it is centered at the station and oriented by means of a short north-south line drawn through the station, the bearings being plotted directly without shifting the protractor.

### *7634. Adjustment of the Dead-Reckoning Plot*

After the distance arcs and the other position data have been plotted in pencil and the dead reckoning for that part of the hydrography has been plotted on tracing paper (see **765**), a study is made of the dead reckoning to fit it best to the distance arcs and the other position data. In areas comparatively close to the R.A.R. stations where most of the bomb distances are reliable, this study is a comparatively simple matter. But where the control is inadequate or unreliable, as is often the case in areas distant from the control stations, the adjustment may be difficult even for one with extensive experience in R.A.R. methods. Continued and determined study in such cases frequently yields results seemingly impossible of attainment when the first attempt at adjustment is made.

The two positions which were used to determine the speed or log factor must not be given too much weight since it is always possible that one of these may be in error in spite of the fact that they were originally selected as being probably correct. It is to be noted that because these were used in determining the speed or log factor the dead-reckoning plot will fit them regardless of their actual accuracy of position.

Occasionally a series of three R.A.R. distances is obtained from one station which is relatively close to the sounding line. If the true azimuth of the sounding line is accurately known, the dead reckoning may be fitted to these three arcs in the same manner it would be fitted to bow, beam, and quarter bearings.

Where the dead-reckoning plot cannot be fitted satisfactorily to the position data, this is occasionally due to the use of an erroneous speed or log factor, in which case the dead reckoning must be replotted.

The outer ends of long offshore sounding lines are perhaps the most difficult to adjust. These are generally far distant from the control stations where the intersections of the distance arcs are weak at best and where, because of the extreme distances, many of the bomb returns are unreliable. Where the line is in extremely deep water, as it generally is, there is an added uncertainty due to the incomplete knowledge of the path of the sound wave in such areas, and consequently the apparent velocity needed for plotting. Some of these dead-reckoning runs are 6 to 8 hours or more long, during which period a considerable change in the leeway may be caused by wind or weather, and a change in the direction of the current, if tidal, may be expected. There is never sufficient knowledge of the current on such an offshore line.

Such offshore sounding loops must be adjusted to the last two or three positions on the offshore run that are believed to be reliable and the first two or three similarly reliable positions on the inshore run. The dead-reckoning plot is adjusted approximately for azimuth to the reliable positions at the beginning of the line. The closing error at the end of the line is adjusted graphically, proportional to time, in the manner that a closed traverse is adjusted. This first adjustment is made on tracing paper. An additional adjustment is usually required to fit it to the R.A.R. data in order to give the distance arcs their appropriate weights. (See **3376** and **3378.**)

If there are crosslines in such an area as has been discussed in the preceding paragraph, a study of the boat sheet should be made to determine how well the respective lines have been controlled. The best-controlled line should be plotted first and the successive lines plotted in the order of the strength of their control. On each line the soundings at the crossings should be tentatively plotted and used as additional control data, the positions of the more poorly controlled lines being influenced by those that are better controlled.

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### *7635. Analysis of Data*

For analyzing the various data, it is not possible to prepare a table of relative weights to apply to the different situations that might arise. Experience is the best guide and much depends on the conditions prevailing at the time of the survey. All three-point sextant fixes should be considered precise locations until proved otherwise. The locus of one sextant angle should likewise be considered a fixed line of position unless proved erroneous. Bearings to near objects will generally be accurate. The acoustic returns from the nearest station will generally be found more reliable than those from more distant stations, except that consistently good returns may be received from certain stations while those from other stations may be just as consistently unreliable. A position determined by a good intersection of three distance arcs may generally be accepted as a reliable position, but it must be remembered that an inaccurate velocity or other factors may cause the arcs to intersect at a position which is not the correct one.

### *7636. Sources of Error in R.A.R. Positions*

Before the final positions are accepted, all conflicting data should be resolved, if possible. Such conflicts may be due to determinable errors, such as those arising in the plotting or in the reduction of the records, or they may be due to certain indeterminable errors inherent in the method itself. The various sources of error may be grouped as follows:

*a. Scaling the chronograph tape.*—A large error is sometimes made in identifying the signal offset on the tape. If this occurs at one position only of a series of positions, and for one distance arc, the error is generally recognizable, but where made at all of the positions of the series it is harder to detect. A large error in all of the time distances at one position is usually easily detected since the resultant arcs plot with a large triangle of error and not in accord with the dead reckoning. An error of 1 second in reading the tape has been found in this manner. (See also **6853**.)

Errors are also sometimes made in scaling the initials on the chronograph tapes. Such an error is more difficult to detect for it may result in a comparatively small triangle of error that may appear to be caused by the use of an erroneous velocity of sound. Errors are occasionally made in marking the bomb return on the tape at the time it is received, especially if this occurs during excessive static conditions or other radio interference, when it is difficult to distinguish the bomb returns from the *strays* or false indications. In such cases a re-examination of the tape will sometimes disclose the correct return, but changes should not be made in the distances in the Bomb Record unless the correct bomb return can be identified on the tape with reasonable certainty. The above are a few of the reasons why the chronograph tapes must be available to the smooth-sheet plotter (see **6854**).

*b. Plotting and reduction of records.*—Errors in drawing the distance arcs on the smooth sheet are not common. An error is occasionally made by plotting the time increment as a decrement from the next larger distance circle or vice versa, where the position falls approximately midway between them. A distance arc may be plotted occasionally from the wrong station. Mathematical errors are sometimes made in converting actual elapsed times to those used in plotting. For this reason, where certain distance arcs appear doubtful, the mathematical conversions should be rechecked in the Bomb Record. (See **8311**.)

*c. The use of an erroneous velocity of sound.*—These cases are not uncommon and they are particularly difficult to detect since an incorrect velocity will proportionally enlarge or reduce the distances from all stations, and the distance arcs will still plot with a very small triangle of error. In analyzing such cases it should be remembered that the correct position will be inside the triangle of error only where the stations are arranged in a triangle around it. A change in velocity will probably alter the distances to all stations proportionally. Therefore, in case of an error in velocity the correct position will be distant from each plotted arc an amount proportional to the distance of each arc from its respective station.

*d. Errors inherent in the R.A.R. method.*—There are certain inherent errors in the R.A.R. method of control of which little is known at present. One of these is that the time interval for an R.A.R. distance from a nearby control station is apparently shorter than it should be. The cause of this and the distance at which the effect ceases to exist are not definitely established, but it has been detected in distances up to 7 or 8 seconds from a station.

Another error, the cause of which is unknown, occurs on lines far distant from the control stations where, with the same sized bomb, the time intervals apparently lengthen slightly more than they should as the survey ship proceeds away from the stations. In such cases, if a change is made to a larger bomb, the excess time distance is apparently reduced. And just the opposite effect is noted when the ship is heading toward the control stations from far offshore.

Since neither the cause nor the magnitude of these errors is known, there is no way of compensating for them. Further experiments in the field may disclose a solution to these and other problems.

*e. Errors in bearings.*—Bearings are only accurate where they are observed to comparatively close objects. In general, those observed to an object not more than 4 miles away may be considered reliable, but some of these and all of those taken at greater distances should be used with caution.

### *7637. Accepting and Inking Positions*

After the analysis has disclosed which distance arcs and position data are reliable and to be used, the exact fitting of the dead reckoning to them and the pricking of the finally accepted positions should be accomplished. The dead-reckoning plot will seldom fit all of the accepted position data exactly. As one position after another is finally decided upon and pricked, it is necessary to shift the dead-reckoning plot small amounts to adjust it to the successively accepted positions.

As the positions are accepted on a given sounding line, the distance arcs shall be inked or left in pencil according to the following rules:

(1) All arcs that are 3 mm or more distant from the accepted position are temporarily questioned and the reduction and plotting are rechecked. If no errors are found and the *arcs are not used* in determining the R.A.R. position, they are left in *pencil* on the smooth sheet and the values are marked "**R**" in the Bomb Record to indicate that they have been rejected.

(2) All arcs within 3 mm of the accepted position that did not influence the location of the position are *inked* on the sheet but are marked with a question mark (?) in the Bomb Record.

(3) All arcs, regardless of their distances from the accepted position, *which have influenced* the location of the position are *inked* on the smooth sheet.

After the accepted positions have been pricked on the smooth sheet they should be inked and numbered (see **7681**) and the distance arcs inked.

For purposes of identification the distance arcs from each R.A.R. station should be inked in a distinctive color. The preferable colors in the order listed are carmine, brown, green, purple, and blue. Where there are more than five R.A.R. stations on one sheet a repetition of colors is necessary. Confusion will be avoided from such duplication if a study is first made of the returns received from the various stations. The assignment of colors should be made by one familiar with the actual field operations of that particular survey. Distance arcs should be inked with an over-all length of 6 or 7 mm, interrupted at the position dot and leaving a space in which to pencil the sounding. Arcs that do not pass through or too near the position may be inked as short continuous lines.

Bearings should be inked as fine black lines, as above, but slightly longer.

After the positions on a sounding line have been inked, the area covered by the line should be cleaned with a soft art gum eraser before connecting the positions. In this the dead reckoning must be used as a guide for changes in course which occurred between positions.

## 764. Plotting Astronomic Positions

Beyond the limit of the usual control, sounding lines are controlled by dead reckoning and astronomic sights. The only data for location of the sounding lines and the positions are the astronomic sights and the carefully recorded dead reckoning. It is usual, when practicable, to observe a series of star sights at dawn and dusk to give positions at these two times. At other times, single astronomic sights, usually sun sights, are taken and these must be used in conjunction with the dead reckoning. (See also **337** and **338**.)

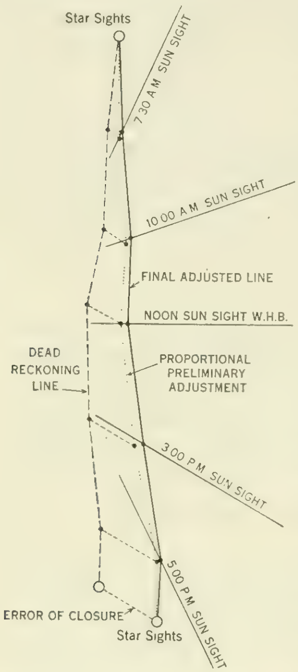



FIGURE 161.—Dead reckoning adjusted to astronomic sights.

In plotting a smooth sheet controlled by astronomic sights, the positions are usually computed and determined on separate records and it is only necessary to plot the most probable positions as determined by the hydrographer. These positions may be considered as fixed positions, a note being placed on the smooth sheet explaining their determination, such as "star sights" (see **3387**). Each intermediate single sight must be plotted as a line of position, accompanied by a legend indicating the astronomic body observed and the initials of the observer (see **3383**). Where all of the astronomic sights between two positions fixed by star sights, have been plotted on the smooth sheet, the dead reckoning between the star sights must be carefully plotted, either on the smooth sheet itself or on a piece of tracing paper, and adjusted to the two end positions and the intermediate sights, taking all circumstances into consideration in order to arrive at the most probable location of the entire line. This type of work can be plotted only by one thoroughly familiar with ship hydrography, navigation, and the probable errors that enter into dead reckoning and astronomic sights. (See **3384**.)

## 765. Plotting the Dead Reckoning

Dead reckoning may be plotted in various ways depending on the accuracy of the hydrographic survey and the purpose for which the dead-reckoning plot is to be used. (See also **337**.)

Where dead reckoning is used alone or in conjunction with astronomic control, since comparatively few changes in course are made, it is generally satisfactory to plot it lightly in pencil directly on the smooth sheet and make an adjustment similar to a traverse adjustment. Where dead reckoning is used in conjunction with R.A.R. control it is almost always preferable to plot it on tracing paper so that it can be adjusted to the other control data. For such purpose a good grade of comparatively thick tracing paper should be used; Keuffel and Esser Ionic No. 197-*H* is recommended. This might at first appear too thick and opaque but actually it is sufficiently transparent and otherwise very satisfactory.

Several steps in the plotting are similar, regardless of the purpose for which it is to be used. Where the dead-reckoning line is long and it is plotted directly on the smooth sheet, the direction of each course should be determined by reference to the

nearest meridian. Where the line is short, changes in course may be plotted by their angular differences, disregarding their true azimuths.

### *7651. Determination of the Speed or the Log Factor*

For the plot of a section of dead reckoning the first step is the determination of the speed of the ship or the log factor, if log distances are used. For this it is necessary to select two well-fixed positions between which only minor changes in course have been made. The actual distance over the ground between these two positions is compared with either the log distance or the time run, in order to obtain a log factor or a speed with which the dead reckoning is plotted. In hydrography controlled by R.A.R. methods it is sometimes difficult to select accurately fixed positions. A good intersection of three distance arcs may usually be depended on as an accurate position, if it is verified by the course and distance between it and an adjacent good position. The speed or log factor should be determined from a comparatively long distance but it must be remembered that speed and log factors differ with different directions of the sounding line. A different speed or log factor must be determined after each major change in direction. (See also **4826** and **4827**.)

### *7652. Dead Reckoning in Conjunction With R.A.R.*

Since there are still numerous uncertainties in the R.A.R. method of control, it is frequently necessary to use a dead-reckoning plot in conjunction with the other data to determine the most probable positions. There are two general cases where this is necessary; first, in areas very close to the control, where for some reason or other the R.A.R. data are inadequate; and second, on the outer ends of long lines distant from the R.A.R. stations where few, if any, R.A.R. returns are obtained. The dead-reckoning plot is made from the data in the Sounding Record supplemented and checked by the R.A.R. abstracts. Where the dead reckoning is plotted by log distances, the use of the R.A.R. abstracts is necessary because only on this form are the log intervals determined. (See also **7634**.)

Dead-reckoning plots are not necessary in connection with all R.A.R. surveys. In areas where the positions are controlled by three R.A.R. distances which plot consistently with good intersections the dead-reckoning plots are unnecessary. On the other hand, where the R.A.R. returns are not consistently and accurately received for any reason whatsoever, the control data should always be supplemented by the dead-reckoning plot; for example, dead-reckoning plots should always be used in plotting the outer ends of offshore sounding lines. It is good training for an inexperienced person to plot the dead reckoning of all of the lines controlled by R.A.R. The dead-reckoning plots may also be advantageously used by the supervising officer in verifying the work of a new employee.

### *7653. Plotting a Dead-Reckoning Line*

There are several methods by which dead reckoning may be plotted, the choice between which depends on the amount which is to be done. Parallel rulers may be used. With them the successive courses may be plotted with reference to a meridian line or by the small angular differences between the courses. A circular no-arm protractor may be used. This is considered a better method than the use of the parallel rulers. In this method each successive course is plotted in azimuth relative to the previous course.

A special compass rose has been found advantageous for making R.A.R. dead-reckoning plots. This is a partial rose about 16 inches in diameter on heavy paper. Each single degree is drawn for about 15° or 20° on each side of a central line extending the length of the paper, and numbered according to its angular distance from the central line. To use this rose a mean course or an approximate direction of the line is assumed with respect to which the successive courses are plotted by differences in degrees. The tracing paper on which the dead-reckoning plot is to be made is placed over the compass rose and weighted down. The successive courses are then plotted on the tracing with reference to the compass rose by the use of two triangles to transfer each direction to the position from which it is to be plotted. In using this special rose it is best to assume an average course of an even 5°.

Dead reckoning may be plotted by log distances or by time. Each method may be preferred under different conditions. If the r.p.m.'s of the engine are reasonably constant and if a careful record of the time has been kept in the Sounding Record, the use of time alone is believed preferable since this eliminates the necessity of computing and checking the log intervals and generally simplifies the work. Log distances are probably slightly more accurate and should be used for all comparatively long dead-reckoning plots. This is only true, however, if the log is an accurate one and the survey is made in waters where there is no floating debris to become attached to the log rotator or log line.

Except on the outer ends of offshore dead-reckoning lines, U-turns (where the direction of the line changes 90° and soon thereafter another 90° in order to put the ship on an adjacent parallel line) are not plotted unless they are necessary to fill a *holiday* in the surveyed area. The recorded data are rarely adequate to plot such turns satisfactorily, unless a fixed position has been obtained between the two 90° turns. Where it is necessary to plot a 90° turn and other evidence is lacking, approximately two-thirds of the distance around the turn should be added to the previous course and one-third of the distance to the new course. (See **3454**.)

During the survey the ship occasionally gets so far off line that an S-turn is required to get back on the original line. It is particularly difficult to plot the dead reckoning of these turns because sufficient data relative to them are rarely recorded. The data needed are the times the vessel begins to turn after each order to change course, the time the vessel is steadied on the new course, and the course and time steered on the intermediate course. (See **3464**.)

Each completed dead-reckoning plot should be the best possible graphic representation of relative courses and distances between fixed positions. Several dead-reckoning plots may be included on one sheet of tracing paper but each one should be properly identified. In order to avoid confusion not more than one day's hydrography should be included on one sheet. The plot should be made neatly and accurately and marked for subsequent easy identification.

All sheets of tracing paper containing dead-reckoning plots shall be transmitted to the Washington Office for use in connection with the verification of the survey, after which they are destroyed.

## 766. DETACHED POSITIONS

The detached positions in the Sounding Record are of the utmost importance, since they are usually taken to locate rocks, floating aids to navigation, least depths on

shoals, or other dangers or features of importance. They must, therefore, be plotted with extreme care. The plotting of positions on a continuous line of soundings is automatically checked to a certain degree by the dead reckoning. There is no such check on detached positions. The survey requirement for important detached positions is that a third, or check, angle shall be taken at such positions. In plotting the smooth sheet this check angle must always be used by the plotter to verify the correctness of his protracting. The fact that this has been done must be indicated in the Sounding Record by a colored pencil checkmark placed after the third or check angle.

## 767. Use of Boat Sheet in Smooth Plotting

### *7671. Comparison With Boat Sheet*

During the protracting of the smooth sheet, constant reference should be made to the boat sheet, as a check on the smooth plotting. Generally, a visual comparison is sufficient, but where difficulty in plotting is encountered or where numerous errors are found in the recorded data, it is sometimes advisable to trace from the boat sheet the positions of an entire line for comparison with the smooth plotting. Where a discrepancy between the two is noted, it must be investigated. Such discrepancies may arise from errors in the smooth plotting; from errors in the boat-sheet plotting; or from errors in the recorded data. In determining the position most probably correct, several facts must be kept constantly in mind, the most important of which is that the boat-sheet position is usually plotted independently of the recorded data. The plotter, himself, has usually observed one of the angles and knows which signals he used. The other angle he obtains orally from the other angleman. Furthermore, the officer-in-charge knows what he is trying to do and where the most probable position of the vessel should be, irrespective of where the recorded data place the position. It frequently happens, either intentionally or unintentionally, that an angle is measured to a different signal from that previously used, but in the haste to plot the position, the change of signal is not reported or is not entered in the Record when it is reported. (See also **3211**.)

Frequently when some error has been made in the observed data, such as an angle observed on a wrong signal or an error in reading the sextant, the boat-sheet plotter may not have sufficient time to determine what this error is. He plots the position as best he can, and may instruct the recorder to question either the entire fix or a part of it. The smooth plotter should study such cases. With a little patience he can often determine what the most probable error is, and can make the necessary correction to the recorded data. Such corrections must be made with a colored pencil (see **7741**).

### *7672. Positions From Boat Sheet*

There are cases in hydrographic surveys where it is impossible to obtain a three-point fix or other position data. This frequently happens in narrow winding channels and sloughs. The hydrographer, in such cases, spots his position on the boat sheet from the adjacent features of the shoreline and from his sense of dead reckoning. The smooth plotter should transfer such positions to the smooth sheet and note that fact in the Sounding Record with his colored pencil. In addition, he should transfer the curved connecting lines between positions, which in narrow channels usually conform to the bends in the shoreline, it being impossible to run a straight course between positions. (See **3252** and **3352**.)

There are occasional cases where position data, although recorded, are so erroneous that they obviously cannot be used. In such cases the smooth plotter's last recourse is the boat sheet. Often by placing the center of the protractor on the boat-sheet position and trying various combinations of angles and signals, he will be able to determine what the recorded data should have been.

## 768. Identification of Positions

Each hydrographic position, regardless of the method used in plotting, shall be marked on the smooth sheet by a small prick hole and identified by the position number, the prick hole being accentuated by a fine ink dot of the same color as the position number and day letter (see **7681**). At the beginning and end of each line, at every intermediate fifth position, and at any pronounced change in the direction of the line, the position number shall be accompanied by the day letter.

### *7681. Position Numbers and Day Letters*

Beginning with number 1, consecutive numbers are assigned to positions during each day, and each day's field work by each vessel is identified by a day letter (see **3311** and **3312**). The day letters inked on the smooth sheet must correspond in color and case with the entries in the Sounding Record, and the position numbers must correspond in number with the entries in the Sounding Record, and in color with the day letters. The colors to be used for this purpose are blue, purple, green, and red, preference being given in that order for the predominant color on a sheet. The use of black and yellow is forbidden (see **8121**). A contrast is desirable between two colors used for this purpose on the same sheet.

Position numbers and day letters are usually inked as each sounding line or page of the Sounding Record is protracted. This is generally often enough to avoid errors. In congested areas, it is sometimes convenient to connect the prick holes representing the positions with pencil lines on the overlay tracing, to assist in their subsequent identification on the smooth sheet.

The position number must be so small that it can never be confused with a sounding, and yet should be large enough so that it can ordinarily be read without a magnifying glass. Vertical figures and letters shall be used, and these shall ordinarily not exceed 1 mm in height. In open areas, where the soundings will be inked larger than average, the position numbers and day letters may also be slightly larger than the average, while in areas of close development, where the soundings will have to be inked smaller than average, the position numbers and day letters should be somewhat smaller than average (see **7732** and fig. 163).

Because of their small size, considerable care should be taken in inking the position numbers and day letters, and in their placement on the sheet. Their purpose is to permit ready comparison of the plotted data with the Sounding Record, and if illegibility makes this difficult, the purpose is defeated.

The position number should be placed preferably just below and to the right of the position dot, with enough space left for the entry of the sounding so that when the latter is inked the position number will be close to, but just below and to the right of it, consideration being given to the size of the sounding to be inked at the position. (See also **7762**.)

In congested areas, and especially in those areas in which considerable development has been done, it is usually advisable not to ink the position numbers and day letters

until after the soundings have been penciled, and certainly they must not be inked in a given area until after all of the positions have been plotted in that area, in order that they may be so placed as not to conflict with the soundings on other lines. Under any circumstances the placement of the position numbers and day letters must indicate indubitably the positions to which they refer. This may be accomplished where necessary by the use of fine inked arrows or leaders from the position number to the position dot, using the same color as for the number.

### *7682. Connecting Positions*

Successive positions shall be connected by a pencil line using a well-sharpened 3H or 4H pencil with a round point—not a chisel edge (see **724**). Care must be taken not to engrave this line in the surface of the paper.

The connecting lines represent the path of the survey vessel, and in drawing them on the smooth sheet the path should be assimilated so far as possible. Both the boat sheet and the entries in the Sounding Record as to changes in course should be used as a guide. Instructions for the field survey require that a position be taken at each change in course greater than 10° (see **3463**). However, it is frequently necessary to make changes in course between positions, which are large enough to affect the locations of the soundings between the positions. Changes in course of 1° or 2° between positions may be disregarded in the plotting and the consecutive positions connected by a straight line, but for greater changes the positions should be connected by lines which follow the actual track of the vessel.

Changes in course are not always effective at the time of the order to change. This depends on the momentum of the vessel. In a launch the effect is almost immediate, while in the larger vessels, some time elapses before the change becomes effective. This fact together with a knowledge of the turning radius of the vessel will determine its path.

Each vessel has its own turning radius, being proportionately larger as the size of the vessel increases. When better information relative to the turning radius is lacking, it may be assumed to be, as a general rule, zero for outboard motor boats, 15 meters for the smaller launches, and 150 meters for the smaller vessels. For the larger ships, unless there is evidence to the contrary, turns should be plotted on the assumption that, after a position, the vessel maintains the original course for twice the distance it is on the new course before the next position is taken (see **3463**). If soundings on turns are to be inked on the smooth sheet, the greatest care must be taken in correctly representing the turns. This is particularly true in the case of right-angled and 180° turns. However, where no soundings have been recorded, only the approximate path need be indicated.

Minor changes in course are frequently made by the hydrographer *after* a position has been plotted on the boat sheet and it is learned what change is necessary. Obviously such changes occur some little distance past the position, although the recorded data may not so indicate. In such cases, if no change in course has occurred between the two immediately preceding positions nor between the two succeeding positions, the connecting lines between these may be extended forward and backward and their intersection will usually represent the point where the change in course was effective.

In narrow winding channels and rivers and sometimes on the inshore line along a rugged coast, it is impracticable to take a position at every turn, since the sounding lines must follow the bends in the shoreline. In such cases the connecting lines must be transferred from the boat sheet, on which the hydrographer will have indicated the correct track. (See **3352**.)

### 769. Plotting Supplemental Data

It is frequently impossible or impracticable to determine the positions of rocks awash, dangerous wrecks, floating aids to navigation, etc., by three-point fixes, or other means described above in section **76**. In areas where the general hydrography is controlled by three-point sextant fixes, such objects are usually *cut in* (see **7415**). In this method of location, cuts may be taken from known shore positions, but more frequently they are obtained during the hydrographic survey by a third observer, who takes a sextant angle to the object simultaneously as the angles for position are being observed. These extra, or third, angles are recorded in the Sounding Record with the position at which they were taken, and the object cut in is described. Three or more cuts from different positions, which will give an adequate angle of intersection, are usually taken to each object.

As the smooth plotting proceeds, these cuts must also be plotted. The boat sheet should be used as a guide for the approximate locations of the objects cut in.

Such cuts rarely result in a perfect intersection and a judicious interpretation of the data is necessary to determine the most probable position of the object. The distance of the object from the vessel, the inherent strength of the position fix, and the size of the angle of the cut must all be taken into consideration. So far as uncertainties in the position fix are concerned, the smaller the angle of the cut the less will be the effect on it due to slight inaccuracies in the fix, especially when the object cut in is at the same approximate distance as the stations used for the fix.

If the object being located is a floating aid to navigation, the direction of the current at each observation should be considered.

Where many cuts have been taken to different objects in an area, it is frequently extremely difficult to be certain which cuts were taken to identical objects, and a careful study of all the facts and data is necessary to avoid the possibility of confusion of cuts.

## 77. SOUNDINGS AND DEPTH CURVES

The soundings are the most important part of a hydrographic survey, and the greatest care must be taken in putting them on the smooth sheet. They must be clear and legible and, in general, a magnifying glass should not be required to read them. The smooth plotter must always bear in mind that an illegible sounding erroneously transferred to a published chart may possibly result in loss of life and property. The fact that the work is verified before publication does not relieve the plotter from exercising care in the first instance.

All soundings are *penciled* on the smooth sheet in the field. Under no circumstances are they to be inked by the field party. This is accomplished only after verification in the Washington Office.

### 771. Depth Units

Only one depth unit (fathoms or feet) shall be used on each hydrographic survey sheet. The depth unit to be used will depend on the general region (in which ocean the survey is located), on the specific locality, and on the unit used on existing charts.

#### *7711. Depth Unit in the Atlantic Ocean*

The depth unit of surveys in the Atlantic Ocean and bodies of water tributary thereto shall be integral feet (and occasionally to the nearest half-foot), except—

(*a*) For those offshore surveys which are entirely beyond the limits of charts whose depth unit is feet; in which case the depth unit of the survey shall be fathoms.

### *7712. Depth Unit in the Pacific Ocean*

The depth unit of surveys in the Pacific Ocean and bodies of water tributary thereto shall be fathoms (and decimals), except—

(*a*) Where the major part of a hydrographic sheet is within the limits of a chart whose depths are in feet, that smooth sheet shall be plotted in feet.

(*b*) That the survey adjacent to the shoreline shall be in feet when the sheets can be arranged, without duplication, so that nearly all of the reduced depths on the inshore sheet are less than 25 fathoms.

### *7713. Fractional Foot Units*

On a hydrographic sheet whose depth unit is feet, the depths shall be in integral feet, *except* in the following cases, where they shall be shown to the nearest half-foot:

(*a*) At important points on navigable bars.
(*b*) At critical places in channels of a general depth of 42 feet or less.
(*c*) The least depth on important shoals, rocks, and dangers when less than 42 feet.
(*d*) In shallow enclosed waters and inside routes.
(*e*) On both sides of the low-water line (see **7715**).
(*f*) Where necessary or desirable to define the depth curves better (see **7762**).

### *7714. Decimal Fathom Units*

On a hydrographic sheet whose depth unit is fathoms, soundings shall be plotted as follows: less than 11 fathoms in fathoms and tenths, between 11 and 31 fathoms to the nearest half-fathom, and greater than 31 fathoms in integral fathoms, *except*—

Where the bottom is smooth and the slope gentle (as in parts of the Gulf of Mexico, the Atlantic Continental Shelf, and the Bering Sea), and a Dorsey Fathometer or instrument of equivalent accuracy is used, soundings less than 31 fathoms shall be in fathoms and tenths and between 31 and 101 fathoms to the nearest half-fathom.

### *7715. Minus Soundings*

Soundings that reduce to heights above the sounding datum (plane of reference) are termed minus soundings, since ordinary soundings are depths below the sounding datum and are considered positive numbers. Minus soundings are shown on the smooth sheet preceded by a minus sign (see **7735**) and should fall inshore of the low-water line, such areas being bare at the sounding datum.

In order that the location of the low-water line may be more precisely delineated on the smooth sheet, the soundings in the vicinity of the line should be plotted to the nearest half-foot (see **7713**(*e*)), extreme care being taken to accompany them with the correct sign.

### *7716. Conversion of Depth Units*

The corrected depths in the "Reduced soundings" column of the Sounding Record from which the smooth sheet is plotted are either in (*a*) integral feet. (*b*) feet and decimals, (*c*) integral fathoms, or (*d*) fathoms and decimals. The double depth unit of fathoms and feet is no longer used.

Although the corrected depths in the *Sounding Record* may change from one unit to another within the area of a survey or within the same Sounding Record, they are all finally reduced to the unit to be used on the hydrographic smooth sheet (see **823**). Only one unit (fathoms or feet) shall be used on any one smooth sheet. Fractions or decimals of the same unit may of course be used.

### A. SMOOTH-SHEET SOUNDINGS

Where the depth unit on a hydrographic smooth sheet is feet, all soundings are in ntegral feet (and occasionally half feet). Where the depth unit is fathoms, all soundings are in integral fathoms or fathoms and decimals. To accomplish this a conversion from the unit of the depths in the Sounding Records is frequently necessary. This shall be done in accordance with the following rules which are also illustrated in figure 162:

(1) Where the same depth unit is used on the smooth sheet as in the Sounding Record, but in integers on the sheet, any partial units shall be converted into whole units by changing 0.75 or more into the next greater integral unit, and changing decimals below 0.75 into the next lesser integral unit (e. g., 2.75 to 3.75 feet=3 feet; 12.75 to 13.75 fathoms=13 fathoms).

(2) Where as in (1) the depth unit is the same but the soundings are to be plotted in fathoms and tenths, partial units shall be converted by changing 0.075 or more into the next greater decimal unit, and less than 0.075 into the next lesser unit (e. g., 2.575 to 2.675=2.6 fathoms).

(3) Where as in (1) the depth unit is the same but the soundings are to be plotted in half units, then 0.25 to 0.75 shall become ½, and 0.75 to 1.25 shall become 1 (e. g., 3.25 to 3.75 feet=3½ feet; 3.75 to 4.25 feet=4 feet).

(4) Where the reduced soundings in the Sounding Record are in a different unit from that to be used on the smooth sheet, they shall first be converted to their equivalent values in the smooth-sheet unit and then apply rule (1) or (2), as the case may require to obtain the values for plotting.

Table 26 illustrates the application of these rules:

TABLE 26.—*Conversion of reduced sounding values to smooth-sheet values*

| Reduced soundings in Sounding Record | | To be plotted on smooth sheet in | Reduced soundings in Sounding Record | | To be plotted on smooth sheet in |
|---|---|---|---|---|---|
| *Feet* | *Fathoms* | *Feet* | *Fathoms* | *Feet* | *Fathoms* |
| −1. 25 | −0. 21 | | −0. 125 | −0. 75 | |
| | | −1 | | | −0. 1 |
| −0. 25 | −0. 04 | | −0. 025 | −0. 15 | |
| | | 0 | | | 0. 0 |
| 0. 75 | 0. 125 | | 0. 075 | 0. 45 | |
| | | 1 | | | 0. 1 |
| 1. 75 | 0. 29 | | 0. 175 | 1. 05 | |
| | | 2 | | | 0. 2 |
| 2. 75 | 0. 46 | | 0. 275 | 1. 65 | |
| | | 3 | | | 0. 3 |
| 3. 75 | 0. 625 | | 0. 375 | 2. 25 | |
| | | 4 | | | 0. 4 |
| 4. 75 | 0. 79 | | 0. 475 | 2. 85 | |
| | | 5 | | | 0. 5 |
| 5. 75 | 0. 96 | | 0. 575 | 3. 45 | |
| | | | | | 0. 6 |
| | | | 0. 675 | 4. 05 | |
| | | | | | 0. 7 |
| | | | 0. 775 | 4. 65 | |
| | | | | | 0. 8 |
| | | | 0. 875 | 5. 25 | |
| | | | | | 0. 9 |
| | | | 0. 975 | 5. 85 | |

### B. CHARTED SOUNDINGS

The soundings on the published nautical charts are either in (*a*) integral feet, (*b*) integral fathoms, (*c*) fathoms and half fathoms, or (*d*) fathoms and quarter fathoms;—but, these charted soundings are from smooth sheets on which the soundings may appear in (*a*) integral feet, (*b*) feet and half feet, (*c*) integral fathoms, or (*d*) fathoms and tenths of fathoms.

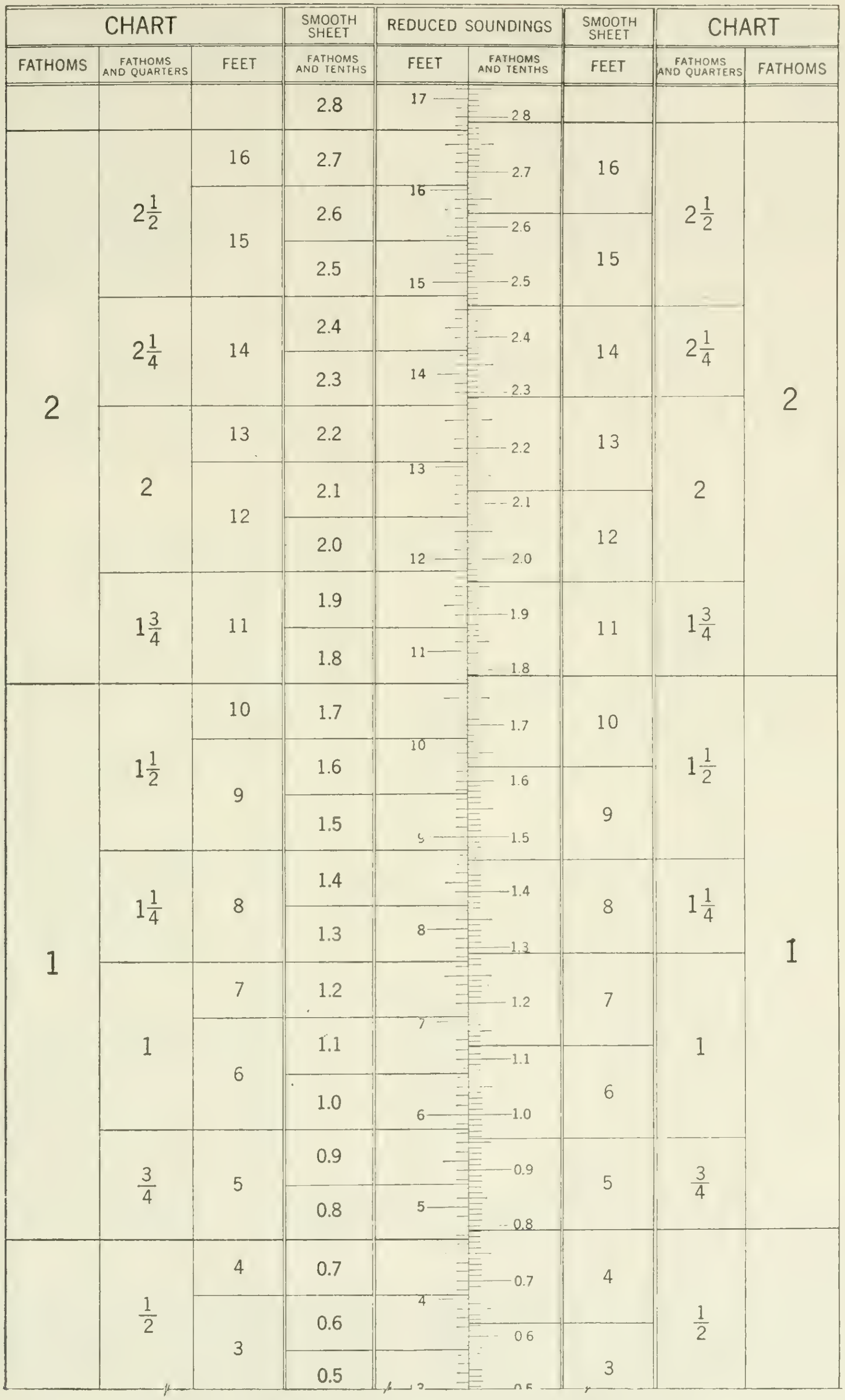



FIGURE 162.—Reduced sounding equivalents for smooth sheet and chart.

It is obvious that it may be necessary to convert from the unit on the smooth sheet to another unit for charting purposes and this shall be done in accordance with the following rules (see also fig. 162):

(1) Where the charted soundings are to be in the same integral unit used on the smooth sheet the soundings shall be transferred without change.

(2) Where a sounding in feet on the smooth sheet includes a fraction, the fraction shall be omitted in charting (e. g. 8½ feet=8 feet).

(3) Where the soundings on the smooth sheet are in integral feet and are to be charted in fathoms and quarters, fathoms and half fathoms, or integral fathoms, the odd feet shall be converted as follows:

| Sounding on smooth sheet | To be charted in | | |
|---|---|---|---|
| *Feet* | *Quarter fathoms* | *Half fathoms* | *Integral fathoms* |
| 1 | 0 | 0 | 0 |
| 2 | ¼ | ½ | 0 |
| 3 | ½ | ½ | 0 |
| 4 | ½ | ½ | 0 |
| 5 | ¾ | 1 | 1 |

(4) Where the soundings on the smooth sheet are in fathoms and tenths and are to be charted in integral feet, integral fathoms, fathoms and quarters, or fathoms and half fathoms, the decimals of fathoms shall be converted as follows:

| Soundings on smooth sheet | To be charted in | | | |
|---|---|---|---|---|
| *Fathoms* | *Integral feet* | *Quarter fathoms* | *Half fathoms* | *Integral fathoms* |
| 0.1 | 0 | 0 | 0 | 0 |
| 0.2 | 1 | 0 | 0 | 0 |
| 0.3 | 2 | ¼ | 0 | 0 |
| 0.4 | 2 | ¼ | ½ | 0 |
| 0.5 | 3 | ½ | ½ | 0 |
| 0.6 | 3 | ½ | ½ | 0 |
| 0.7 | 4 | ½ | ½ | 0 |
| 0.8 | 5 | ¾ | ½ | 1 |
| 0.9 | 5 | ¾ | 1 | 1 |

## 772. Plotting the Soundings

To avoid soiling the smooth sheet during the penciling or inking of the soundings, it should be kept completely covered, except for the small area actually being worked on. A convenient method is to use a large piece of celluloid about 2½ feet square with a circular hole, 3 to 4 inches in diameter, cut in its center, the celluloid being moved around as necessary during the work. Paper can be used instead of celluloid, but celluloid has the advantage of permitting the work to be seen through it. Other parts of the sheet can be kept covered with convenient sized pieces of obsolete charts or wrapping paper. (See **731**.)

The plotting of the soundings on the smooth sheet follows generally the same procedure used in plotting the positions; that is, the plotter usually begins with position 1 of "A" day and plots the soundings in the order in which they were actually taken in the field. This procedure is, of course, not a requirement, and it may be advantageous to depart from it in special cases.

All soundings that are penciled or inked on the smooth sheet shall be spaced according to the recorded time, or the travel of the paper in the case of fathograms, and spacing dividers (see **4813**) shall always be used for this purpose. No deviation

from the recorded times shall be made for the purpose of improving crossings, or for other reasons, unless other data prove that the recorded times are in error. Such errors usually occur only in the hours or minutes, and if the interval between positions is relatively short, as it usually is in three-point fix hydrography, an error in the minutes is easily detected.

Where the depths between positions are uniform, a slight displacement in the positions of the soundings is immaterial, and no appreciable time should be expended in obtaining precise spacing. In irregular depths, however, the spacing as recorded must be closely followed.

All soundings must be plotted on the pencil lines connecting consecutive positions (see **7682**).

Where soundings fall close to control stations in the water area, care must be taken that the soundings do not obscure the actual station points. In general, in unimportant areas of uniform bottom, soundings should not be shown inside a station symbol. But there should be no hesitancy to break the station symbol to show an important sounding.

### *7721. Spacing Three-Point Fix Hydrography*

In three-point fix hydrography positions are usually taken at regular intervals and at even minutes of time (see **3313**). This simplifies the plotting of the soundings between positions. If the soundings are taken at uniform intervals, as is generally the case in handlead work, the spacing dividers are used to subdivide the distance between positions into the required number of spaces, and the soundings are plotted. If the sounding interval is not uniform, the soundings must be plotted according to their respective times. In such cases the spacing dividers are used as a time-measuring device. (See **343** and **4813**.)

When the speed of the vessel is changed materially between positions it must be taken into account in spacing the soundings. This is particularly important in launch and small-boat hydrography at the beginning of lines near the beach, where the launch or boat starts from a standstill or slow speed, increasing to full speed soon thereafter. A similar allowance is often necessary near the end of a sounding line near the beach where the speed may be reduced as the launch approaches the shore. Occasionally, such changes are made far offshore; as for instance, when it is necessary to slow down to avoid collision with a passing vessel. Because of momentum, of course, the increased or decreased speed is effective only gradually after the time noted in the Sounding Record. (See also **3461**.)

### *7722. Spacing R.A.R. Hydrography*

In R.A.R. hydrography, positions do not necessarily coincide with even minutes of time, and as the soundings are recorded according to time intervals there will not always be a sounding on the position; neither can the soundings be spaced evenly from position to position. In using the spacing dividers the points must be set according to time, starting with the minute immediately preceding or following any R.A.R. position which does not occur at an even minute (see **4813**). Otherwise, soundings controlled by R.A.R. are spaced in a manner similar to that used in other methods of control.

*a. Tabulation of crossings on R.A.R. sheets.*—Because of the relative weakness of R.A.R. control in certain areas a penciled tabulation of the depths at crossings shall

be made for each R.A.R. sheet and included in the Descriptive Report (see **842*K***). This will give some idea of the relative accuracy with which the hydrography has been controlled, if the depths are accurate. This tabulation can be most conveniently made as the soundings are plotted on the sheet. At each crossing the depth differences are computed and when these data are available for the entire sheet, percentages are computed which will give a reasonably fair idea of the accuracy with which the survey has been controlled.

### *7723. Spacing Echo Soundings*

Because of the possibility of obtaining an almost infinite number of soundings when the echo method is used, there are frequently more soundings recorded than can or should be shown on the smooth sheet. Echo soundings are spaced in the conventional manner, except that a certain percentage of those recorded will often have to be omitted from the smooth sheet. In echo sounding, soundings are frequently recorded at irregular intervals, but these are usually more important than those recorded at regular intervals, because they define irregularities in the general slope of the bottom. (See **3423**.)

Where soundings are penciled on the smooth sheet directly from a fathogram, clock time is not necessarily used to determine the spacing. The printed fathograms used on the 808 Fathometer contain equally spaced vertical arcs, by which the spacing of the soundings may be determined. When a fathogram is used, the three-point fixes are often taken at the exact moment the stylus is marking on one of the vertical arcs, and irrespective of clock time, with the interval between positions being determined by the number of spaces between position arcs rather than by the number of minutes and seconds. When soundings from such a record are to be transferred to the smooth sheet, the spacing dividers should be adjusted between any two consecutive positions on the smooth sheet so that each divider point represents a vertical printed arc on the fathogram, if the scale permits. When this is done each divider point on the smooth sheet represents the position of the vessel when the sounding was recorded on one of the vertical arcs. In any case, the divider points should be adjusted to a definite relation with the printed arcs, rather than to the clock time, as is necessary for soundings recorded in a Sounding Record. Where three-point fixes have been obtained which did not coincide with one of the vertical arcs, the method is similar except that fractional parts of the spaces between the position arcs must be considered in making the spacing divider adjustment on the smooth sheet in relation to the positions, so that each divider point will still represent a printed arc.

Mechanical spacing of soundings derived from a fathogram is not to be tolerated. Selection should be made as described in **7726**, plotting the soundings on the smooth sheet in their correct positions between the points of the spacing dividers by reference to their positions between corresponding vertical arcs on the fathogram.

### *7724. Frequency of Soundings*

The scale of the smooth sheet and the sounding interval will ordinarily be selected so as to permit all soundings recorded in the Sounding Record to be shown on the smooth sheet. The frequency of recorded soundings is, of course, greater in shallow than in deep water, and this may result in more soundings being recorded than can be shown on the smooth sheet. In this case selection is necessary (see **7725**).

Where the appearance of the smooth sheet is the only criterion, the following rules may be used for general guidance, always bearing in mind that legibility and clearness are of prime consideration:

(1) Where the horizontal axis of the numeral approximately parallels the direction of the sounding line, 1-digit numerals should be spaced about 7 to an inch, 2-digit numerals about 5 to an inch, and 3-digit numerals about 4 to an inch.

(2) Where the horizontal axis of the numeral is approximately normal to the direction of the sounding line, the most satisfactory spacing is about 7 numerals to an inch.

(3) Where numerous fractions, or decimals, are to be shown, these may be considered as equivalent in width to about one-half digit.

In congested areas at least 50 percent more soundings can be legibly shown in the same space without undue confusion, if care is used (see **7732** and fig. 163).

### *7725. Selection of Soundings*

Where all of the recorded soundings are not to be shown on the smooth sheet a careful selection must be made so that those shown will most nearly represent the actual bottom relief. In no case, except where the bottom is practically flat, shall a mere mechanical selection be used, as for instance the selection of alternate soundings. The sounding obtained on a fix should always be shown. Between fixes, where a selection is necessary, the general rule is that both the deepest and shoalest soundings must be shown, interspersed with as many other soundings as can be conveniently shown. It is absolutely essential that the final result show the least depth on shoals, the greatest and least depth in channels, all changes of slope, and those soundings which are essential to the correct delineation of the depth curves.

In penciling soundings on the smooth sheet, it is essential that dangers and important depths be not obscured by numerous soundings of lesser importance. As the progress of penciling reveals the important features it will frequently be found necessary to delete some of the plotted soundings to permit showing those of more importance. To assist in drawing attention to important features, such as rocks awash, sunken rocks, and least depths on shoals, frequent use shall be made of leaders pointing to these (see **7753**).

The low-water line is one of the most important depth curves on the smooth sheet, and it is essential that it be located as accurately as possible. All of the soundings that will aid in defining its location shall be shown in pencil on the smooth sheet. (See **754**.)

At crossings of sounding lines and occasionally where two parallel sounding lines approach one another closely, the soundings of one line will conflict in position with those of another line. In selecting the soundings in such cases, the same considerations must govern as in the case where all the soundings on one line cannot be shown. In general, the least depth should be selected.

Where soundings have been taken over even mud or sand bottom and there is a plethora of soundings of approximately the same depth, it is unnecessary to show them with the frequency used for uneven bottom. In such cases they should be plotted with only about two-thirds the frequency stated in **7724**.

Recorded soundings that are not used in the smooth-sheet plotting should be marked "N.P." in the Sounding Record, the notation being entered in color (see **7624**) after the final reduced sounding.

465382—44——47

### *7726. Selection of Soundings From Fathogram*

Where the depths are recorded on a fathogram a different problem is presented. In this case, soundings are selected from a continuous profile of the bottom along the line traversed by the sounding vessel. The smooth plotter must have an appropriate spacing in mind at all times, but he must not select the soundings by any regular spacing. The soundings selected should, insofar as their frequency permits, present a numerical record that will approximate the graphic profile. In all cases the least depth of a rise in the bottom must be selected, and this must be followed and preceded by the greatest depths, where practicable, irrespective of any intermediate soundings. Likewise, the greatest depth of a depression in the bottom must be selected. In very irregular bottom the number of these to be shown will be regulated, of course, by the number of soundings that can be legibly shown on the smooth sheet in a given space. Intermediate soundings shall be selected which will best delineate the actual profile.

## 773. Penciling the Soundings

In penciling the soundings, the smooth plotter must use every effort to achieve clarity. Critical soundings should never be obscured by placing soundings of lesser importance too close to them. A pencil hard enough to prevent smudging should be used, but it must not be so hard as to indent or cut the surface of the paper. Generally, a 3H pencil will be found satisfactory, but this will depend on the humidity of the atmosphere at the time (see **724**).

As each day's soundings are penciled the plotter shall enter his initials with a colored pencil in the appropriate space in Stamp No. 38, Processing, placed in the Sounding Record at the end of each day's work (see fig. 183).

### *7731. Style of Numerals*

The penciled soundings shall be bold vertical numerals, drawn with single strokes. Hair line or fancy lettering must not be used. The beginner will usually experience some difficulty in penciling soundings neatly with even-sized numerals, but skill is easily acquired with a little practice.

### *7732. Size of Numerals*

Most of the numerals representing soundings should be about 2 mm in height. The size of the numerals, of course, should vary somewhat according to whether the soundings are sparse or congested in any given area. In areas where the soundings are sparse the size should be increased about 10 percent, and in congested areas should be reduced about 10 percent. Ordinarily, no sounding numeral should be less than 1.8 mm in height, although even this limit may have to be lowered for areas in which the soundings would otherwise be illegible. The important things to remember are, first, that *no sounding* should ever be illegible and, second, that in order to present a pleasing appearance a uniform size of numeral should be maintained as far as practicable. (See fig. 163.)

In areas of intensive development where individual lines of soundings are difficult to follow, the numeral representing the least depth should be drawn slightly larger and bolder. Such depths are the most important soundings in the area, and a cursory examination of the sheet should disclose these without the need for a meticulous sounding-by-sounding examination of the areas. (See also **7753**.)

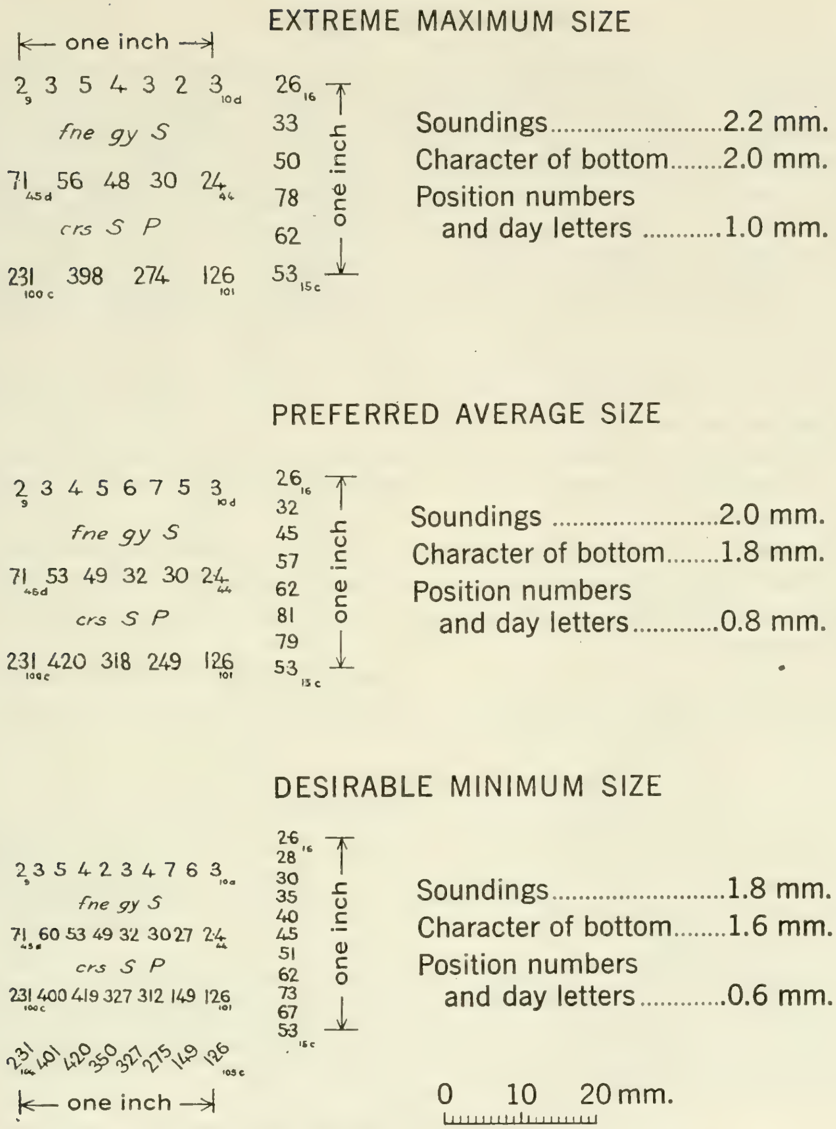



FIGURE 163.—Sizes and placement of sounding numerals and other data on smooth sheet.

When the soundings are inked in the Washington Office the same procedure shall be followed and in addition, care must be taken to maintain the opaqueness of the inked data.

### *7733. Orientation of Numerals*

Regardless of the direction of the sounding line on the projection, all numerals representing soundings shall be oriented to be read from the south. Normally, the horizontal axis of the numbers shall be east and west. Where the numbers contain too many digits or the soundings are too frequent to permit this, they may be inked at any convenient angle, provided they can be easily read from the south (see fig. 163). It should *never* be necessary to turn the sheet to read a part of the soundings easily.

### *7734. Fractions and Decimals*

Figures in a fraction or the decimal parts of a depth unit must be smaller than whole numbers. In general, the over-all height of a fraction should not be more than 15 percent greater than the over-all height of the whole numbers in that vicinity. Where a fraction stands alone the horizontal bar between the numerator and denominator must be included, in order to avoid mistaking the component parts of the fraction for whole numbers. But if the sounding is a mixed number—that is, where a fraction accompanies a whole number—the bar shall be omitted.

The decimal part of a fathom shall be considered as the numerator of a fraction whose denominator is 10, but with the denominator omitted, and shall be so penciled and subsequently inked on the smooth sheet. The horizontal bar which is normally used between the numerator and denominator of a fraction shall be retained as a line under the decimal part of the sounding.

No depth shall ever be shown as a decimal alone. Where the depths are less than 1 fathom, on a smooth sheet whose depth unit is fathoms, the decimal part shall be preceded by zero, as $0^{\underline{3}}$.

Greater care must be taken in penciling and inking fractions and decimals than is necessary with whole numbers, since their smaller size requires greater perfection in the formation of the numerals, in order that they shall be perfectly legible in spite of their reduced size.

In congested areas it is particularly important that fractional numbers be so drawn and so spaced that no doubt can ever arise as to whether a fraction stands alone or is part of an adjoining number.

### *7735. Zero and Minus Soundings*

Where zero soundings are placed on the smooth sheet, extreme care must be taken in drawing these figures in order that they will not be mistaken for off-lying rocks or islets. This is especially important along rocky coasts where small isolated bare rocks or islets are frequent.

A minus sounding (see **7715**) should be preceded by a minus sign (e.g. −2). If the minus sounding is a fraction, the minus sign shall precede the *numerator*, and not be on a line with the bar between the numerator and denominator, since in the latter case it might be mistaken for a part of the bar. (See also **7734**.)

### *7736. Position of Numerals*

The center of the number, including the fraction if any, is considered the position of that sounding and shall be so penciled and inked on the smooth sheet, except for the soundings at positions.

In penciling or inking soundings at positions it is important not to obscure the position dot by any part of the number. Therefore, in those cases, where the number is composed of an even number of digits, considering the fraction, if any, as one digit, the sounding shall be placed with an equal number of digits on each side of the position dot. Where the number is composed of an odd number of digits it shall be placed as follows: (*a*) one-digit numbers immediately to the right of the position dot; and (*b*) three-digit numbers with the first digit to the left, and the second and third digits to the right of the position dot.

### 7737. *Vertical Casts*

In conjunction with echo sounding, occasional comparisons are made with vertical casts taken by the leadline or wire method. Such simultaneous soundings are both to be placed on the smooth sheet, in pencil; the echo sounding at the correct position and the vertical cast immediately beneath it and connected to it by means of a bracket.

After verification in the Washington Office, only the echo soundings shall be inked in areas of comparatively regular bottom. Where vertical-cast comparisons occur in areas of steep slopes or very irregular bottom, both the echo sounding and the vertical cast are inked, the latter being marked "VC".

## 774. ERRORS IN SOUNDINGS AND POSITIONS

During the plotting of the soundings and the delineation of the depth curves, the smooth-sheet plotter must be ever alert to detect errors in the Sounding Records, whether in the original entries or in the final reduced depths. In spacing the soundings with the spacing dividers, previously undiscovered errors in the plotted positions may often be disclosed, which may have resulted from original erroneous or inadequate data, or from errors made by the plotter. As the soundings are penciled, errors in the depths may be disclosed by the fact that the soundings on adjacent lines are not consistent, or by the fact that when the depth curves are drawn they are forced into representations of unnatural bottom features.

If errors are discovered or suspected, they must be verified and corrected wherever necessary. But no deviation from the original recorded data shall be made unless this appears reasonable and is supported by other evidence. Where any entry in the Record is amended or rejected, such changes shall be made in colored pencil (see **7741**) and each change fully explained or justified by a note in colored pencil in the "Remarks" column.

Two general classes of errors may occur in the Sounding Records; those which affect the positions of the soundings and those which affect the depths. And of these two classes certain types of errors will affect only isolated soundings or positions, while others will affect an entire area. The latter, of course, are the most difficult to discover.

In **7624A**, there have been listed the kinds of errors found occasionally in the recorded position data which affect the positions of the soundings on the smooth sheet. Errors of position may also result from the following sources:

(*a*) Faulty spacing of the soundings along the sounding line, due to—
 (1) An error in plotting the soundings.
 (2) A failure to take into account variations in course or speed in plotting the soundings.

(*b*) One of the sextants badly out of adjustment.

(*c*) One or more of the control stations incorrectly plotted.

(*d*) In R.A.R. control, the use of an erroneous horizontal velocity of sound for one or more of the distances. (See also **7636**.)

(*e*) Small clock errors.

(*f*) An omission of variations in course or speed in the Sounding Record.

Erroneous soundings may result from an almost infinite variety of causes, of which the following are the more common:

(*a*) A confusion of numbers in the Sounding Records, such as the interchange of 7 and 11 or 15 and 50, where the soundings obtained are transmitted orally to the recorder (see **4623**).

(*b*) A misread sounding; that is, the leadsman or fathometer attendant actually reports a sounding different from that obtained.

(c) An inaccurately calibrated sounding apparatus or the misapplication of the corrections, among which may be the following:

(1) Leadline not compared with the standard.

(2) Leadline varied in length between standardizations.

(3) Sounding machine registering sheave not correctly calibrated.

(4) An erroneous velocity of sound used in the reduction of echo soundings.

(d) Erroneous application of any of the data used in reducing the soundings.

(e) Large clock errors which may result in an erroneous tide reduction.

(f) An inaccurate plane of reference; errors from this source may occur where—

(1) The tide gage is located at too great a distance from the area being sounded.

(2) The area being sounded is blocked by shoals from free access of the tide.

(3) The tide gage is so located that the free rise and fall of the tide, particularly the low water, is not correctly recorded.

(g) A rough state of the sea—errors due to this condition may be detected where one day's work performed in rough weather is adjacent to another day's work performed in calm weather; or where crosslines have been run in an area under different conditions of sea from those which obtained at the time the principal system of lines was run.

(h) Where the leadline or wire is not perfectly vertical—such condition occurs when the sounding line is run in a wind, sea, or current, handlead soundings being particularly vulnerable in this respect (see **3464**); wire soundings in deep water may be similarly affected because of the impossibility or impracticability of maintaining the position of the vessel vertically over the lead (see **3422**).

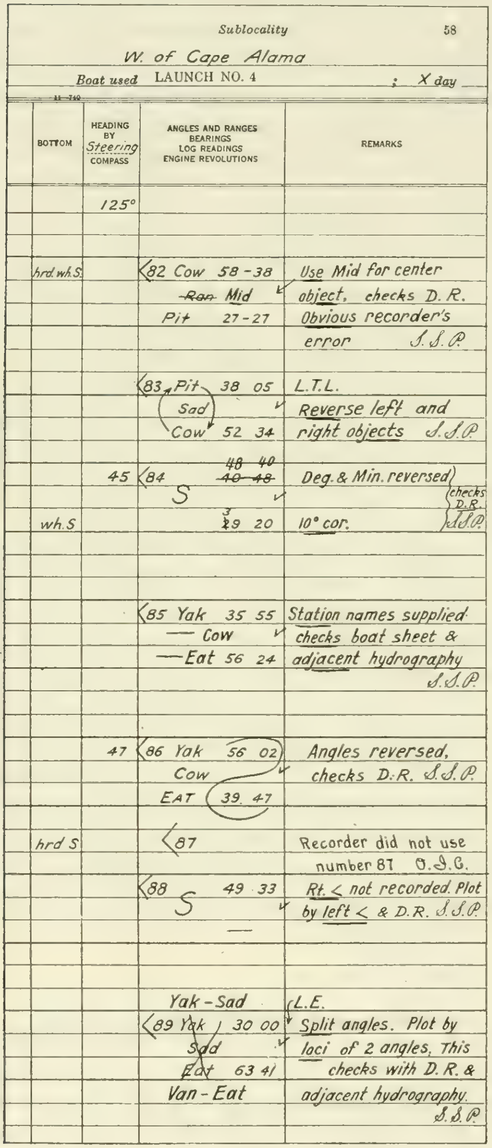
(i) Where handlead or wire soundings are taken in an area of very soft or oozy bottom, where it is difficult or quite impossible to detect when the lead strikes the top of the soft layer.

(j) Where soundings are taken on abrupt slopes:

(1) In handlead or wire soundings the lead may slip down a rocky slope.

(2) In echo sounding, the sound may be reflected from the side of the slope rather than from vertically beneath the vessel (see **563**).

(3) A small displacement of the position of the sounding may affect the depth by a considerable amount.



Sublocality W. of Cape Alama 58

Boat used LAUNCH NO. 4 ; X day

| | BOTTOM | HEADING BY Steering COMPASS | ANGLES AND RANGES BEARINGS LOG READINGS ENGINE REVOLUTIONS | REMARKS |
|---|---|---|---|---|
| | | 125° | | |
| | | | | |
| | | | | |
| | hrd.wh.S | | <82 Cow 58-38 | Use Mid for center |
| | | | ~~Ran~~ Mid | object, checks D.R. |
| | | | Pit 27-27 | Obvious recorder's |
| | | | | error S.S.P. |
| | | | | |
| | | | <83 Pit 38 05 | L.T.L. |
| | | | Sad | Reverse left and |
| | | | Cow 52 34 | right objects S.S.P. |
| | | | | |
| | | 45 | <84 ~~40 48~~ 48 40 | Deg. & Min. reversed |
| | | | S | checks D.R. |
| | wh.S | | 3 9 20 | 10° cor. S.S.P. |
| | | | | |
| | | | | |
| | | | | |
| | | | <85 Yak 35 55 | Station names supplied |
| | | | — Cow | checks boat sheet & |
| | | | —Eat 56 24 | adjacent hydrography |
| | | | | S.S.P. |
| | | | | |
| | | | | |
| | | 47 | <86 Yak 56 02 | Angles reversed, |
| | | | Cow | checks D.R. S.S.P. |
| | | | EAT 39 47 | |
| | | | | |
| | hrd S | | <87 | Recorder did not use |
| | | | | number 87 O.S.G. |
| | | | <88 49 33 | Rt. < not recorded. Plot |
| | | | S | by left < & D.R. S.S.P. |
| | | | — | |
| | | | | |
| | | | | |
| | | | Yak-Sad | L.E. |
| | | | <89 Yak 30 00 | Split angles. Plot by |
| | | | Sad | loci of 2 angles. This |
| | | | Eat 63 41 | checks with D.R. & |
| | | | Van-Eat | adjacent hydrography. |
| | | | | S.S.P. |
| | | | | |

FIGURE 164.—Right-hand page of Sounding Record with corrections properly made (reduced about one-half).

### *7741. Corrections to Recorded Data*

The instructions for recording the data forbid erasures, and recorders correct their errors by crossing out the erroneous entry and writing the corrected one above or at one side (see **81**). The smooth plotter may frequently find that the rejected entry, or some part of it, was correct, but that its application may not have been correct.

An example of a right-hand page from the Sounding Record of three-point fix hydrography is illustrated in figure 164. Typical errors and omissions are shown, together with the proper method of checkmarking and correcting them. The corrections should be made by the smooth-sheet plotter according to the following general instructions:

(*a*) All corrections and notes in the Record must be made in colored pencil, the same as used for checkmarking the positions (see **7624**), in order that it will be clear what data were used for plotting the position and that it was not a correction made in the field at the time of recording the data.

(*b*) The original recorded data shall never be erased, no matter how certain the plotter may be as to the correct entries. Such corrections should be made by crossing out the recorded data and, where practicable, entering the correct data above the erroneous data. But in any case, the correct data should be so entered that no mistake in interpretation can be made.

(*c*) The reason and authority, if any, for the revision shall be entered.

After the smooth sheet has been completed, it should be in complete agreement with the corrected Sounding Record. No positions should appear on the smooth sheet except those which are based on data in the Sounding Record, or are fully explained by supplemental entries; neither should any depths be penciled on the smooth sheet which do not appear in the Sounding Record or on the fathogram. It should be possible at any time in the future to justify any information on the smooth sheet by reference to the Sounding Record or fathogram.

## 775. Congested Areas

Cases frequently occur where it is impossible to show adequately parts of surveys at the scale of the smooth sheet. Among these are: (*a*) intensely developed small areas; (*b*) soundings taken in small docks and alongside small piers; (*c*) large water areas developed with two or more systems of lines. Clarifications in (*a*) and (*b*) are accomplished by means of subplans at enlarged scales (see **7751**), and in (*c*) by means of overlay tracings (see **7752**).

### *7751. Subplans*

Small congested areas shall be shown at enlarged scales in subplans in otherwise blank spaces on the smooth sheet, where practicable. The scale and extent of the plan

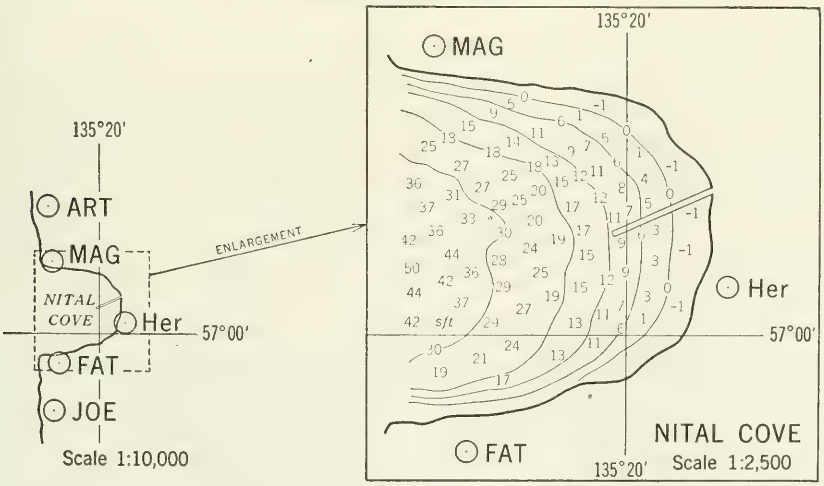



FIGURE 165.—Subplan of small cove on smooth sheet.

shall be large enough to show the positions and soundings clearly, and to include the stations used to control the hydrography to be plotted thereon.

Enlarged subplans, such as those to include the water area of a small bay, bight, inlet, or anchorage area, shall be surrounded by a heavy margin in black ink. Each subplan must include the scale, the name of the water feature, if any, and at least one meridian and parallel. An arrow should be added leading to the plan from that part of the smooth sheet of which the plan is an enlargement, where it can be done without interference with the hydrography. A fine dash pencil line should be drawn around the area on the original scale which has been enlarged. Details shown in the enlargement may be omitted from the original scale. Wherever practicable, the subplan should be located so that its meridian and parallel coincide with two of the lines of the principal projection. (See fig. 165.)

Where soundings are taken in small docks and along the sides and ends of small piers and are located by reference distances to or along the piers, enlarged plans of these

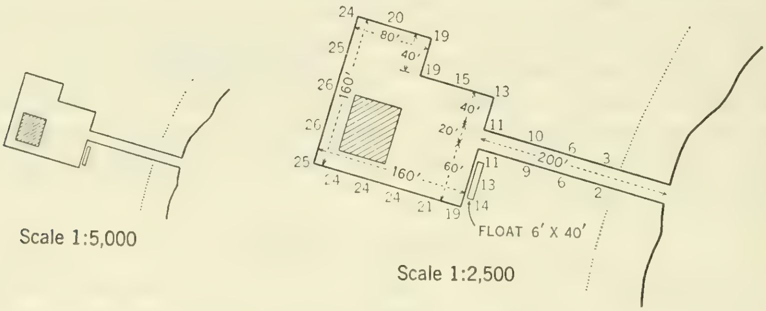



FIGURE 166.—Subplan of pier with soundings alongside.

shall be shown as nearby as convenient to the areas at the original scale. If the enlarged plan cannot be shown adjacent to the area, there shall be an arrow leading to the enlarged pier from that place on the shoreline where the pier is located. Such plans need not contain a scale nor be surrounded by a margin. Each plan shall show in figures the principal dimensions of the pier. (See fig. 166.)

### 7752. *Overlay Tracings*

Where the subplan method is impracticable, because of the extent of the area involved, or for any other reason, *overlay tracings* shall be used. These are plottings on tracing cloth, at the scale of the smooth sheet, of one or more of the several systems of sounding lines used to develop the area. In order to achieve clarity, it is sometimes necessary to use more than one overlay. The overlays need be only large enough to include the hydrography in question, and need not cover the entire sheet. The protracting is done directly on the tracing using the control points on the smooth sheet. Both positions and soundings on the overlay shall be inked (positions in black and soundings in red).

Each overlay tracing shall be referenced to the smooth sheet by number as "Overlay to accompany H-5236," and shall be marked by a sufficient number of projection intersections, at least two of which shall be identified by their latitudes and longitudes.

Smooth-sheet plotters may determine where overlay tracings are necessary and what portion of the work should be so prepared by the criterion that it must be possible for the verifier to identify each position on the various sounding lines. As a general rule, where the sounding lines are not much less than one-fourth inch apart, two systems of lines may be satisfactorily plotted directly on the smooth sheet, but where there are

more than two systems the additional systems should be plotted on one or more overlay tracings.

If, for example, there are three systems of sounding lines, *A*, *B*, and *C*, in an area, system *A* should be plotted and the soundings penciled directly on the smooth sheet. The position dots should be inked but the position numbers and day letters should be left in pencil at this stage of the plotting. It is often advantageous to identify the positions temporarily by placing the numbers and day letters well outside of the congested area, connected to their respective positions by lightly penciled leader lines. The second system, *B*, if neither *A* nor *B* is too closely spaced, should then be plotted directly on the smooth sheet in the same manner as *A*. In penciling the soundings of system *B* it will be found that some of these occur where soundings from system *A* have already been penciled, and it will be necessary to erase some of the *A* soundings to make space for shoaler soundings obtained on the *B* system. The resultant soundings on the smooth sheet should be an adequate selection from the *A* and *B* systems, depending on the depths obtained. No preference should be given to the soundings of one system over the other. After the soundings have been penciled, the position numbers and day letters can be inked where they will not interfere with the soundings, using short leaders where necessary.

The hydrography of system *C* should now be plotted on the overlay tracing, with the least depth found by that system emphasized by an arrow pointing to it, on which is lettered the depth, position number, and day letter.

Finally, the least depth obtained from all of the systems on any given shoal must be plotted on the smooth sheet and indicated by a leader at whose end in a clear space is given the depth, and the position number and day letter (see **7753**).

All overlay tracings must be forwarded to the Washington Office with the smooth sheet. When the latter is verified in the Office the positions will be transferred from the overlays to the smooth sheet, and a selection of soundings made which will adequately represent the depths in the area; after review of the smooth sheet the overlays will be destroyed.

### 7753. *Least Depths*

The least depth on each shoal, whether or not it contains intensive development, should always be shown slightly larger and bolder than the surrounding depths, in order that it will not be overlooked even in a cursory examination of the smooth sheet. (See **7732**.) And in all cases where there is any doubt about the least depth being readily noticeable, there should be added, in pencil, a legend "Least depth ---- ft" in a clear space (on the land area if necessary) with a fine arrow, or leader, drawn toward the minimum depth. The position number and day letter should also be given if not otherwise clear.

If available, a bottom characteristic should always be added as near the least depth as practicable.

The same general procedure shall be followed when such least depths are inked in the Office, except that the position numbers and day letters will ordinarily not be inked in the legend.

## 776. DEPTH CURVES

*Depth curves*, or curves of equal depth, are shown on the smooth sheet for the purpose of bringing clearly to the eye the general configuration of the bottom, and for emphasizing important navigational features, such as shoals and channels. They are also of value in studying the adequacy of the survey in the Office, where areas are often discovered that require additional field examination.

Depth curves are comparable to contours on land, each curve representing an imaginary line on the ground (in the water area), every point of which is at the same depth below the sounding datum. The principles which govern the delineation of land contours are equally applicable to the drawing of depth curves, and a knowledge of topographic expression and submarine relief is essential for their correct representation. A study of the characteristic bottom forms in any region is of value in the interpretation of hydrography, as such forms usually repeat themselves in similar regions, and often in the same region. (See **3531** and **355**.)

Abnormal or improbable depth curves are strong evidence of probable uncertainties or inaccuracies in the hydrographic survey or the reduction of records, and the soundings

or positions controlling such abnormalities should always be verified before acceptance as correct (see **353**).

Depth curves shall be *penciled* on the smooth sheet before it is transmitted to the Office. The colors adopted to represent the various depth curves on hydrographic surveys are listed in table 27. Depth curves on smooth sheets are only inked in the Washington Office after the survey has been verified.

TABLE 27.—*Depth curves*

| Curve in fathoms | Curve in feet | | To be inked in |
|---|---|---|---|
| 0 | 0 | (Plane of reference) | Yellow. |
| ½ | 3 | (*Omit*) | Violet. |
| 1 | 6 | | Green. |
| 2 | 12 | | Red. |
| 3 | 18 | | Blue. |
| 4 | 24 | (*Omit*) | Yellow. |
| 5 | 30 | | Red. |
| 6 | 36 | (*Omit*) | Green. |
| 10 | 60 | | Yellow. |
| 20 | 120 | | Blue. |
| 30 | 180 | | Violet. |
| 40 | 240 | | Green. |
| 50 | 300 | | Red. |
| 100 | 600 | | Green. |
| 200 | | | Yellow. |
| 300 | | | Violet. |
| 400 | | | Green. |
| 500 | | | Red. |
| 1, 000 | | | Blue. |
| 2, 000 | | | Yellow. |
| 3, 000 | | | Violet. |

### *7761. Selection of Depth Curves*

All of the applicable depth curves listed in table 27, except as modified under this heading, shall be penciled on the smooth sheet. However, if the survey includes significant submarine features which are not emphasized sufficiently by the use of the curves listed, additional curves should be drawn. The nonstandard curves and the reason for using them should be given in the Descriptive Report (see **842*J***).

Although they will ordinarily not be inked (see **7763**), the 4- and 6-fathom curves shall always be penciled on the smooth sheet by the field party, and the ½-fathom curve shall be added where it may be useful in small-boat navigation.

Occasionally some of the depth curves should be omitted for reasons of clarity. On steep slopes the curves may be so closely adjacent as to be confusing; in such cases the shoalest and the deepest curves are generally the most important and should be shown, omitting the less important intermediate ones. Where rocks or steep shoals rise suddenly from much greater depths one or more of the deeper depth curves should frequently be omitted; for instance, if a 5-foot depth on a rock is surrounded by general depths of 20 feet or more, the 6-foot curve must be drawn, but the 12- and 18-foot curves may be omitted. In channels with steeply sloping sides, the curve which gives the maximum through depth is the most important and should be shown at the expense of some of the shoaler curves. Likewise, where islands, shoals, or reefs rise abruptly from

much greater depths and several of the shoaler depth curves are very close to the shorelines of the islands, or edges of the reefs, the shoaler curves should be omitted.

### *7762. Delineation of Depth Curves*

Depth curves shall be penciled lightly as continuous lines, using a 2H pencil, and using as a guide the curves shown on the boat sheet. The hydrographer will have sketched on the boat sheet, many more depth curves than are required for the smooth sheet (see **3533**), and in doing this, certain characteristics of the submarine relief are developed that may not be apparent where the prescribed curves only are drawn. Careful attention must, therefore, be paid to the boat sheet when drawing the curves on the smooth sheet.

Depth curves are drawn so that each depth corresponding to the depth indicated by the curve is either on the curve or within it. Where the curve passes between soundings, it must be located at the correct proportional distance between the two depths. Curves must be broken at sounding numerals and position dots—never continued through them as continuous lines. At position numbers, however, curves should be continuous, the numbers being moved slightly, if necessary.

In comparatively shoal depths where there may be dangers to navigation, one should always err on the side of safety in drawing depth curves. Where the soundings are not spaced closely enough to determine precisely the position of a depth curve, the curve must be drawn to include the part of the area in which a shoal sounding is possible. For example, where there is a shoal of less than 3 fathoms extending offshore, around which the depth curve might be closed just outside of several 3-fathom soundings on a given line, and there is one sounding of 3 fathoms or less on the next adjacent line offshore, the one sounding must not be surrounded by a detached curve, leaving the inference that there are greater depths between the 3-fathom detached sounding and the inshore 3-fathom curve. On the contrary, the curve must be extended to include the isolated sounding, as in figure 167. Similarly, where there is an absence of soundings between two contiguous shoal areas, the depth curve must be drawn to connect both shoals, rather than as a closed curve around each one, since in the latter case the inference would be that depths greater than the depth curve exist between the shoals. (See fig. 167.)

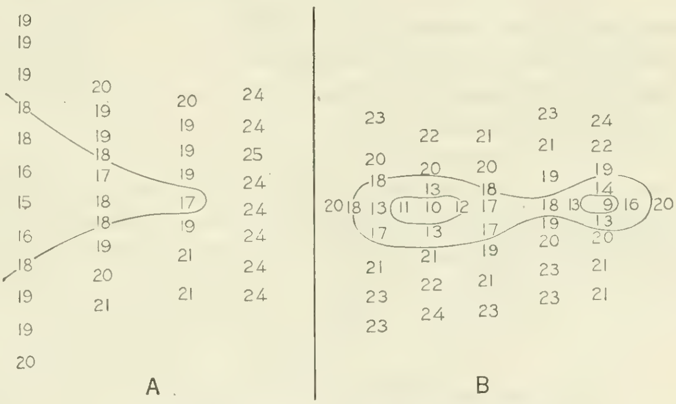



FIGURE 167.—Depth curves in vicinity of shoals (see text).

Without exception, depth curves should never indicate a through channel unless this has been proved by the actual soundings taken.

Over extensive flat areas it is frequently advisable to add fractional depths in the vicinity of the depth curves in order to locate them more accurately (see **7713**).

Depth curves or parts of curves that are not well defined, as where they are dependent on one or two soundings, shall be shown as broken lines, except where close inshore, in which case they shall be omitted entirely.

The low-water line, or zero depth curve, is one of the most important curves on the smooth sheet. Where it is not well defined by the soundings, data from other sources as prescribed in **754** should be used for its delineation.

### *7763. Inking the Depth Curves*

The depth curves are inked in the Washington Office following the colors given in table 27. The word "omit" opposite a depth in the table indicates that ordinarily that curve is not to be inked. Any curves not inked shall be erased by the verifier.

Nonstandard curves penciled by the smooth-sheet plotter to delineate submarine features not sufficiently emphasized by the standard curves (see **7761**), shall be inked in brown on the smooth sheet by the verifier. (See also **9336** and **9342*b***.)

## 777. INSPECTION OF PLOTTING

After the positions and the soundings have been plotted and the depth curves and the bottom characteristics (**783**) have been added, the work shall be inspected by a responsible person for completeness and accuracy. In addition, the depth curves and the differences in depths at crossings and between adjacent sounding lines should be critically examined.

The inspection should also include an examination of all critical soundings to ensure that they are clear and legible; there should be no doubt, under any circumstances, as to the least depth on any rock or shoal. Neither should there be any doubt about the deepest draft that can be carried safely through any channel, along any recommended course, or through any particular areas where passage of vessels is frequent.

### *7771. Differences in Depths at Crossings*

Where excessive differences at crossings are encountered in a survey, a study of the results should be made in order to discover, if possible, the source of the trouble and to make such corrections as are necessary. Such differences may be due to some fault in the sounding apparatus or in the method, or some error in the record. What is to be considered excessive will depend on the strength of the control, the accuracy of the sounding method, and the character of the bottom. It is impossible to formulate a rule which will cover all of these variable conditions. One experienced in hydrographic work will recognize, for any set of conditions and any given area, what differences are excessive.

Where differences in depth are discovered, all the possible causes must be considered, and almost any one discrepancy may result from either an error in position or an error in depth. It is particularly important to remember this, especially in areas of steep slopes, where a slight displacement in the position of the sounding may account for the difference in depth. (See also **563**.)

The allowable difference in any given case should not be based on a percentage of the depth, but rather on the lateral displacement of the depth curves. In compar-

atively even bottom, such as exists in the Gulf of Mexico, a difference of 2 or 3 feet may be excessive, because of the amount the depth curve is displaced. On the other hand, in areas of steep slopes a difference of several fathoms may be readily allowable since the position of the depth curve may not be affected appreciably.

If the control is strong, excessive differences should not be caused by uncertainty of positions except in cases of pure blunder. Individual cases of excessive differences may result from an error in protracting or from an error in the reduction or plotting of the soundings, and the first step in the elimination of such errors is to verify the positions and depths in the vicinity of the discrepancy. Where crosslines have been run on a different date from the original system of lines, the discrepancies may be due to differences in sea and weather conditions on the two dates; and these should be examined.

A statement shall be made in each Descriptive Report relative to the discrepancies at crossings (see **842*K***). Generally, this may consist of a simple statement of the percentage of crossings at which the differences are 1, 2, 3, etc., percent of the depth. Because of the relative weakness of R.A.R. control in certain areas, a complete tabulation of the depths at all crossings shall be made for each R.A.R. sheet (see **7722*a***).

#### *7772. Examination of Depth Curves*

The best evidence as to the adequacy and completeness of the survey is whether the depth curves can be completely drawn, and whether their shapes and convolutions are natural. A study of the depth curves may disclose discrepancies from several sources. Where the depth curves do not represent normal types of bottom relief, some source of trouble is to be sought. For example, a tide gage inadequately located with reference to the hydrography will result in depth curves having a jagged unnatural appearance if based on adjoining parallel lines run at different stages of the tide.

A study of the depth curves, and a consequent study of the hydrography in the vicinity, may also reveal discrepancies due to the use of different methods of sounding or the use of different sounding instruments, and may result in actual corrections being made to some of the lines of soundings and in rejections of others.

## 78. ADDITIONAL DETAILS ON SMOOTH SHEET

### 781. Explanatory Notes

A variety of miscellaneous explanatory notes is required on the smooth sheet before it can be considered complete. Such notes should be made as short as practicable and still give the desired information. (See fig. 171.) Those referring to hydrographic features shall be in slanting letters, and those referring to land features shall be in vertical letters. The lettering should be freehand, upper and lower case, the average height of the capital letters being 1.8 mm, the lower-case letters being proportionately smaller. Notes should ordinarily begin with a lower-case letter. The size of the lettering should be consistent throughout each sheet, in order to present a pleasing appearance. In congested areas it may be reduced in order to conserve space, but the letters should never be so small as to require a magnifying glass to read them.

A good deal of latitude may be taken in the placement of notes, as long as it is perfectly clear to which feature a note applies. This may be accomplished in many cases by the use of leaders (see **7914**).

Unless stated otherwise under the specific paragraphs, all explanatory notes placed in the land area or in clear spaces in the water area shall be inked in black, but those that must be placed in the sounded area should be left in pencil for subsequent inking in the Washington Office, after verification of the survey.

Periods shall not be used under any circumstances in connection with names, notes, or any symbol that appears in the water area, as they might be confused with bare rocks. (See also **783**.)

In addition to the types of notes referred to above and those specifically mentioned elsewhere in this Manual, the following general classes of notes are required. These apply mostly to control stations and landmarks, and should be shown in vertical lower-case letters, and in parentheses (see fig. 171).

(*a*) The name of each marked recoverable topographic station shall be followed by the word "marked".

(*b*) The name of each recommended landmark shown on the hydrographic sheet shall be followed by the word "landmark", together with the elevations above the ground and above mean high water, if known; and if the name is not self-explanatory, a few words describing the object should be added (see **7844**).

(*c*) Each object in the water area used as a signal shall be explained by a note stating whether it is of temporary or permanent nature, and if permanent its character must be described for the information of the cartographer in charting (see **7444**).

(*d*) Each control station that is a natural or artificial object and is permanent or semipermanent shall be briefly described in one or two words immediately following the station name.

(*e*) If the source of the position of a control station is other than the official records of the Bureau, an explanatory note shall be added after the station name to state the source of the data.

## 782. ROCKS, REEFS, LEDGES, AND ROCKY AREAS

The representation of these features is one of the most important phases in the plotting of a smooth sheet. Great care is necessary in order that there shall be no ambiguity regarding their true character and that the conventional symbols used for such features conform to the adopted standards in part "O" of the Symbols and Abbreviations chart (see fig. 189, part IX).

In applying these features to the smooth sheet, those that originate solely with the hydrographic survey or that result from an adjustment between the hydrographic and topographic data should be left in pencil by the field party (see **7827**). All other features (and primarily these include information transferred from the topographic survey) should be inked in black unless otherwise noted in this Manual. Similar treatment should be followed in the case of descriptive notes or elevations accompanying such features. (See **7825** and table 28.)

### *7821. Planes of Reference or Sounding Datums*

In the hydrography of the Coast and Geodetic Survey two general planes of reference (sounding datums) and one special plane are in use. They are mean low water (MLW) for the Atlantic and Gulf areas, mean lower low water (MLLW) for the Pacific areas, and mean low water springs (MLWS) for the Pacific entrance to the Panama Canal (see **8224**). The plane of mean high water (MHW) is the datum to which the shoreline and all land elevations are referred (see **2311**).

All rocks, reefs, and ledges shown on the smooth sheet must be referred to these planes, and to no others, and they must be symbolized in accordance with the rules given in **7823**.

### *7822. General Definitions*

Three types of rocks may be encountered in a hydrographic survey, characterized as bare, awash, and sunken. By convention and for general purposes, they are defined in relation to the tidal datums of the locality, as follows:

(*a*) *Bare rocks* are those extending above the plane of mean high water.

(*b*) *Rocks awash* are those exposed at any stage of the tide between mean high water and the sounding datum, or that are exactly awash at these planes.

(*c*) *Sunken rocks* are those covered at the sounding datum, that are potentially dangerous to navigation.

For cartographic purposes, however, the general definitions have been modified in order that the charted symbols may reflect the most probable condition of the rock as seen by the mariner. On smooth sheets, therefore, the rules in **7823** shall be followed in the delineation of the data relative to rocks, reefs, and ledges. (See also fig. 168). The rules are, of course, not inflexible, and in their application consideration should be given to the character of the area, whether exposed or protected; the proximity to shore; the range of the tide; and the extent of the minus tides; the controlling factors in all cases being the emphasis on dangers and the probable visibility of the rock at some stage of the tide. (See **9334***a*.)

Regardless of the sounding datum, references to Atlantic Coast include all areas in the Atlantic Ocean and the Gulf of Mexico, and references to Pacific Coast include all areas in the Pacific Ocean and in Alaska.

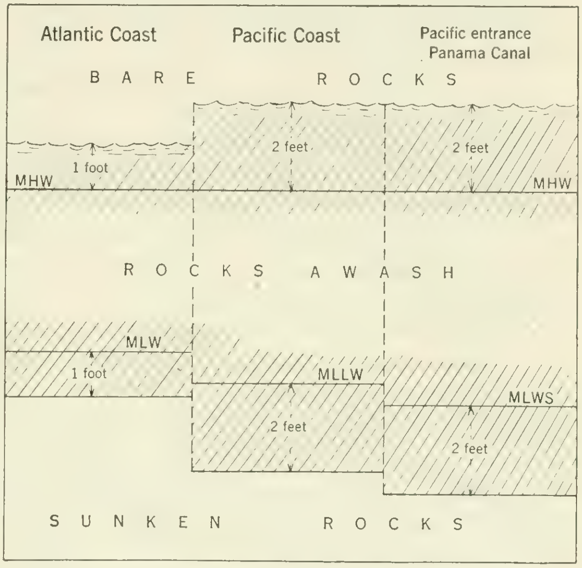



FIGURE 168.—Relationship of rocks to tidal datum planes.

### *7823. Rules of Application*

*a. Bare rocks.*—Rocks with elevations of 1 foot or more above mean high water on the Atlantic Coast, or 2 feet or more on the Pacific Coast, shall be shown as bare rocks. The actual shape of the rock should be shown if it is more than one-half millimeter in diameter on the survey sheet, otherwise it should be indicated by a dot. (See fig. 169.)

*b. Rocks awash.*—Rocks shall be represented by the *awash* symbol where their summits are in the zone between 1 foot above mean high water and 1 foot below the sounding datum on the Atlantic Coast. On the Pacific Coast the limits are 2 feet. The same applies to reduced soundings in rocky areas, that are surrounded by depths considerably greater than the soundings. These limits are for reduced depths in the Sounding Record.

The symbol for a rock awash is three crossed lines, one of which is parallel to the lines of latitude.

*c. Sunken rocks.*—Rocks potentially dangerous to navigation, whose summits are below the lower limit of the zone for rocks awash, are classed as sunken rocks, and are represented on the smooth sheet, either by symbol (a simple cross), or by a sounding accompanied by the legend "*Rk*" depending on the nature of the available information.

(1) The symbol should be used where the depth over the rock has not been definitely determined, as in case of transfer from the topographic survey, or where breakers have been cut in but no soundings taken, or where the depth obtained does not represent the least depth over the rock.

(2) The sounding, with legend "*Rk*" appended, should be used in all cases, where the depth on the rock is known, and where the rock, at the sounding datum, is covered 1 foot or more on the Atlantic Coast or 2 feet or more on the Pacific Coast.

(3) The abbreviation "*Rk*" may be appended to the sunken-rock symbol where there is risk that the latter may be overlooked or mistaken for a defect in the paper.

(4) Under no circumstances shall both the least depth and the symbol be used to represent the same rock.

*d. Accuracy of location.*—Any specific rock (bare, awash, or sunken) which has been accurately located by a rod reading, a three-point sextant fix at the rock, or sextant or planetable cuts forming a good intersection at the rock, shall be encircled by a dotted line to distinguish it from those rocks whose positions are estimated, or are from generalized symbolization.

If a rock is so located by the topographic survey, the dotted line shall be in black ink. If located by the hydrographic survey, the dotted line shall be left in pencil to be inked in red after the smooth sheet is verified in the Washington Office (see fig. 169).

It is to be noted that the dotted line is *not* to be used around rocks located by estimated distances from a sounding line.

### *7824. Reefs and Ledges*

A *reef* is a rocky or coral elevation dangerous to surface navigation, which may or may not be above the sounding datum in elevation. A rocky reef is always detached from shore, but a coral reef may or may not be connected with the shore. A *ledge* is a rocky formation connected with and fringing the shore, and is generally above the sounding datum in elevation. These terms should always be so used in the Sounding Records, and will be construed in accordance with these definitions, unless information from other sources indicates otherwise.

These features when bare or awash at the sounding datum must be clearly marked on the smooth sheet to show their nature and extent. They may be represented by symbol or by broken line and legend depending on which method will show the feature correctly and clearly with the least amount of work. A small reef or ledge, for example, might be shown by symbol but a large reef or ledge extending a considerable distance along the shore may be indicated more economically by a broken line with an appropriate legend.

There is no distinctive symbol for a submerged reef or ledge, and where the limits have been determined they should be indicated by a broken line, enclosing sunken-rock symbols or an appropriate legend (see **7826**).

No distinction is made between the symbol for a rocky reef and a ledge. Where a reef is continuous at the sounding datum, the standard rocky-ledge or coral symbol, as the case may be, should be used (see fig. 189, part II), but where the reef is generally submerged and projects only in spots above the sounding datum, rock-awash symbols should be used to represent the protuberances and sunken-rock symbols, the depressions.

From their very nature, the exact delineations of reefs and ledges are sometimes unobtainable from a single source. Therefore, in plotting such features on the smooth sheet, their limits and extent should be based on all available information from the Sounding Records, the boat sheet, and the topographic survey. Care should be taken to distinguish between positions outlining a reef, and those outlining a sandy low-water line interspersed with rocks awash.

### *7825. Elevations and Notes*

All notes and elevations relative to rocks should be referred to the precise datum planes applicable, and not to a generalized one. For example, "uncovers 2 ft at MLW"

should be used and *not* "uncovers 2 ft at LW". Bare rocks should be referred to *mean high water* (MHW) and rocks awash to the sounding datum (MLW, MLLW, or MLWS), except that rocks awash at mean high water should be so designated (see **7823**). Elevations above any datum should be given in feet to the nearest whole foot. Descriptions, such as "breaks at half tide", "breaks in heavy weather only", and the like, are of value for charting and should be shown on the smooth sheet wherever the information has been obtained. Judgment is required in the selection and proper placement of notes in order to avoid crowding the sheet with a multitude of unimportant notes, but no important danger should ever be shown by symbol alone.

*a. Bare rocks.*—The elevations in feet of bare rocks should be shown by slanting figures, in parentheses, close to the feature. If they originate with the topographic survey they shall be shown in red, otherwise in pencil to be subsequently inked in black in the Washington Office. (See also **755** and **782**.)

*b. Rocks awash.*—Elevations of rocks awash above the sounding datum may be indicated either by notes, such as "uncovers 2 ft at MLW" or by slanting figures alone, in parentheses and underscored, as for example (*2̲*). (See part "O" of the Symbols and Abbreviations chart, fig. 189, part IX.) If awash at the sounding datum or at mean high water, a note such as "awash at MLLW" should be used. No rigid rules need be followed, however, in the use of one form or the other. It is left mostly to the discretion of the smooth-sheet plotter. Generally, however, it is desirable to use notes in the case of isolated rocks, or for the highest rock in a group of offshore rocks, or for the outermost rock of a number of alongshore rocks. In congested areas or for the many less important rocks the underscored figure should be used.

*c. Reefs and ledges.*—The above considerations also apply to the notes and elevations of reefs and ledges above the sounding datum or to the rocks awash in a generally submerged reef or ledge.

### *7826. Rocky Areas*

Where, owing to heavy seas, low tide, draft of vessel, etc., it has been impossible to sound in an area with a rocky bottom, but which is otherwise clear of rocks, the approximate danger limit should be indicated by a line of sunken-rock symbols.

Where, owing to a multitude of scattered rocks, it is needless to sound in an area, the positions of the off-lying rocks should be determined and the unsounded area should be marked "foul—unsurveyed". (See also **7824**.)

Where large areas, unimportant for navigation, have not been thoroughly surveyed, as where thick beds of kelp border the shore or where an extensive foul area exists in a remote locality, the outer limits should be shown on the smooth sheet and an appropriate legend added inside. For kelp, the symbol should be used and the area should contain the legend "heavy kelp, not navigable, not thoroughly surveyed". For a foul area, a dash line should be used enclosing the legend "foul, not thoroughly surveyed". (See **3623*b*** and **367**.)

### *7827. Reconciliation of Topographic and Hydrographic Data*

As is noted in **75**, discrepancies between the topographic and hydrographic surveys as to the location and character of rocks should be harmonized in the field by a further examination if necessary, and all differences reconciled in the Sounding Records, on the sheets, and in the Descriptive Reports before submitting the survey to the Office.

Where it is not feasible to investigate the discrepancies further, or to consult the topographer, the smooth-sheet plotter should then evaluate all the information available from both sources, taking into consideration the strength of the position determination, the proximity of the surveyor to the feature, the stage of the tide, etc., and resolve the

differences in favor of the weightier evidence. Generally, the following rules will be found applicable:

*a. Bare rocks.*—Their locations and elevations should be accepted from the topographic survey except where there is unmistakable evidence of incorrectness, or where it is obvious that the topographic location is weak. Where discrepancies between the two surveys result from the rules given in **7823** for interpreting the sounding data, then the source that makes the rock a bare rock shall govern. (See **7825***a*.)

*b. Rocks awash.*—The locations of such rocks should generally be accepted from the topographic survey and should seldom be modified by the hydrographic survey. Their elevations above the sounding datum should be taken from the hydrographic survey because of the more definite tidal information available, and the closer proximity of the hydrographic party to such features.

*c. Sunken rocks and breakers.*—The locations of sunken rocks and breakers, and notes relating thereto should be accepted from the hydrographic survey, but it should first be determined that the identical feature is involved.

Changes in the character of rocks should not be made on the topographic survey where the differences are consistent with the stage of tide at the time of survey, but an explanatory note should be added to the topographic Descriptive Report.

## 783. BOTTOM CHARACTERISTICS

After the soundings and depth curves have been penciled the bottom characteristics should be *penciled* on the smooth sheet. Standard abbreviations have been adopted for such information (see part "S" of Symbols and Abbreviations chart, fig. 189, part XI) and these must be used on the smooth sheet, even if nonstandard abbreviations have inadvertently been entered in the Sounding Record. It should be noted that lower-case letters are used throughout for adjectives, to distinguish them from nouns which all begin with capital letters. Periods must not be used after abbreviations, nor are hyphens or other connecting symbols to be used between abbreviations, but there should be a slight space between them. A standard bottom characteristic should appear on the smooth sheet thus: "*hrd S Sh P*". (See also **384**.) Attention is called to the fact that "*rky*" is the abbreviation for rocky bottom, but the abbreviation "*Rk*" is used only for a rock which rises from much greater surrounding depths, and not for even rocky bottom (see **7823***c*).

In placing the bottom characteristics on the smooth sheet a judicious selection should be made. If a large number are recorded, as is usually the case in areas surveyed by handlead or wire sounding, probably only part of those need be shown on the smooth sheet. On the other hand, where echo sounding is used, comparatively few bottom characteristics are obtained, and probably all obtained should be shown on the smooth sheet, including those whose locations are somewhat indefinite. Bottom characteristics obtained when anchoring and picking up buoys and when observing temperatures and salinities should be shown on the smooth sheet, if an approximate location has been given.

Harbors, anchorages, and shoals are the areas where bottom characteristics are most important. Each shoal must show a bottom characteristic, if one has been obtained thereon. In harbors and anchorages, a sufficient number should be plotted to show, particularly, where changes in the character of the bottom occur; but where there is a monotonous sameness in the character and quality of the bottom, too many characteristics should be avoided. (See **3842**.)

Bottom characteristics should, if practicable, be placed on the smooth sheet reasonably close to and a little below and to the right of the soundings which they

accompany. Where such placement interferes with the clarity and legibility of the sounding, the bottom characteristic should be placed in any convenient space in the immediate vicinity of the accompanying sounding. The abbreviations should be lettered in single stroke slanting letters, the capital letters having an average height slightly less than the soundings and the lower-case letters correspondingly smaller. (See fig. 163.)

After the smooth sheet has been verified, the bottom characteristics will be inked in black in the Washington Office. At that time, if it appears that an insufficient number were obtained, the new survey may be supplemented, on direction of the Chief of Surveys Branch, with bottom characteristics from prior surveys (see **3842** and **9333***b*).

### *7831. Silted Areas*

The fathograms of echo-sounding instruments operating at supersonic frequencies show quite clearly, under certain conditions, layers of silt or other loosely distributed sediment overlying the substrata. These are commonly found in bays, lakes, or estuaries, where silt-laden streams have deposited their loads, or in offshore basin areas where unusual conditions may permit the deposition of silt.

A record of the existence and limits of such sedimentary layers is often of considerable importance. Where encountered in an area being surveyed, the Washington Office shall be notified of the apparent features and special instructions will be issued if a smooth-sheet record is desired.

In such cases the silted areas shall be noted on the smooth sheet, at the time the soundings are plotted, and the approximate outline of each area more than 1 inch in diameter or 1 inch wide, shall be shown by a dash pencil line. A notation explaining their significance shall be made on the title sheet and in the Descriptive Report. The outlines will be inked in a brown dash line after verification in the Washington Office, and at the time of inking the depth curves.

Where silted areas are so frequent that they will be confusing on the smooth sheet or may be confused with the depth curves, their limits shall be shown in brown dash ink lines on a tracing-cloth overlay. The overlay shall be referenced to the smooth sheet by projection intersections throughout the area and shall be identified by a title, as "Overlay showing silted areas on H-5236." A notation shall be placed on the title sheet (Form 537) that such an overlay accompanies the smooth sheet.

Where silted areas are disclosed by the fathograms a discussion of their estimated frequency, sizes, and apparent thicknesses shall be made in the Descriptive Report, irrespective of whether their outlines are shown graphically on the smooth sheet or on an overlay.

## 784. AIDS TO NAVIGATION

All aids to navigation, fixed and floating, within the area of the survey, shall be shown on the smooth sheet. The positions of fixed aids located by triangulation shall be shown by standard triangulation station symbols; where located by topographic or hydrographic methods, control station symbols shall be used if the aids were so used during the hydrographic survey; otherwise, nautical chart symbols should be used (see fig. 169). The positions of floating aids, irrespective of method of location, shall be indicated by the actual aid symbols and colors used on the nautical charts of the Bureau. (See part "L" of Symbols and Abbreviations chart, fig. 189, part VIII.)

The smooth-sheet plotter shall compare the plotted information with that shown on the charts and with that given in the most recent edition of the Light List published by the United States Coast Guard, and any material disagreement as to position or characteristics shall be noted in the Descriptive Report (see **842*P***). The positions of all fixed aids shall also be reported on Form 567. (See also **383**.)

Hydrographic survey parties are required to obtain the depths at all aids to navigation located in the water area, and these shall be shown in pencil similar to other soundings.

Where items **7841** to **7847** inclusive specify that certain data are to be left in pencil by the plotter, they shall be inked in black after verification at the Washington Office.

### *7841. Fixed Aids to Navigation*

Fixed aids fall into two classes, lighted and unlighted, and their correct respective designations are "lights" and "beacons."

In the case of lights, the light sector shall be shown graphically and the limit of visibility in miles given, in pencil, if these have been determined during the hydrographic survey. The characteristics of the lights need not be shown on the smooth sheet.

All fixed aids that have been rebuilt since the date of a previous determination of position, whether or not they are reported to have been rebuilt in the same position, are relocated by the survey party, but must not be referred to as recovered stations. The earlier determinations are *lost* stations and no reference to them shall be made on the smooth sheet. (See also **3831**.)

Where an abandoned light structure is still prominent, its position shall be determined. If it is not located by triangulation, nor used as a control station, it shall be shown on the smooth sheet as a landmark (see **7844**).

### *7842. Floating Aids to Navigation*

Floating aids to navigation are divided into two classes, buoys and lightships. Their positions are usually determined by the hydrographic party, either by three-point fixes or by cuts (see **3832**). Standard symbols are used to represent them on the smooth sheet (see **784**). The small dot at the lower end of the buoy symbol or the small circle at the bottom of the lightship symbol indicates the position of the aid. The type of buoy should be indicated by the correct symbol, and the number of masts on a lightship should also be indicated by the symbol used.

The symbol for a buoy is an elongated diamond shape with its longer axis 2.7 mm in length and its shorter axis 1.2 mm. The dot is 0.8 mm distant from the shape on line with the long axis.

Buoy symbols are best made by means of a celluloid template cut to a slightly larger size than the above dimensions so that when the pencil outline is drawn on the sheet, it will be of the required size. (See fig. 153.)

### *7843. Names of Aids to Navigation*

Care must be taken that the aids to navigation are identified by their correct names, which in all cases shall be assumed to be those given in the latest edition of the Light List. (See fig. 169.)

(*a*) The Light List names of all aids to navigation must be shown on the smooth sheet. If the aid has a station name which is identical with that given in the Light

List, it shall be shown in accordance with **744**. If an arbitrary station name has been used in the hydrography, the Light List name shall then be added in *red*, upper and lower case, slanting letters, in parentheses, immediately below or adjacent to the station name.

There are also frequent cases in which the position of a fixed aid has been determined in the past and it is designated in the triangulation records by a name differing from the correct one. In such cases the name, as given in the Light List, shall be shown, immediately followed by the incorrect name and date of location in parentheses. *Example: Bay Shaft Light* (SAND POINT LIGHTHOUSE, 1887).

(*b*) Beacons, where shown by chart symbols, should be identified by their numbers only, thus: *No. 31*, with the number underlined in blue where located by sextant. Where they are shown by control station symbols, the designation should also indicate the color of the beacon. Example: (*B Bn No 31*). This should be placed immediately below the station name, and in parentheses. (See fig. 169.)

(*c*) Buoys do not ordinarily have station names, but they must be identified by their classification and number placed immediately adjacent to the symbol. Examples: *N 12*, *C 5*, *S 3*, etc.

(*d*) Where the position of an abandoned light structure is shown, the name must be followed by the word "unused", in black ink and in parentheses, to show it is not in use as a light. *Example:* BIRD ISLAND LIGHTHOUSE (unused).

(*e*) The size of the lettering to be used for names of aids to navigation should be somewhat smaller than that used for station names (see **744**).

### *7844. Landmarks*

A special report on recommended landmarks for charts is required on Form 567 (see **8534**). Each landmark, so reported, that is within the limits of the topographic or hydrographic survey must be plotted on one or the other of such sheets. If a landmark is located by triangulation, the triangulation station symbol shall be used; where located by topographic or hydrographic methods, control station symbols should be used if the objects were used as control stations during the hydrographic survey; otherwise, the landmark symbol, a small black ink circle, 2 mm in diameter, should be used. If shown on the topographic sheet, it is not necessary that it also be shown on the hydrographic sheet, if it is not otherwise needed thereon. It is probable that most of the landmarks so reported will have been used as signals to control the hydrography, and therefore, will be indicated by station symbols with their corresponding station names. To identify these as recommended landmarks, the landmark name as reported on Form 567 shall be shown in black ink and in parentheses after the station name, and the word "landmark" in black ink shall be placed in parentheses below the station name, accompanied by the elevations (also in black ink) of the landmark above the ground and above mean high water, if these are known. (See fig. 169 and **8534**A.)

The hydrographer frequently determines that certain large buildings and structures, not recommended by the topographer, are suitable for landmarks. If these have not been used as signals they should be plotted on the hydrographic survey, the position of each being indicated by the landmark symbol, accompanied by the landmark name (also in black ink) as reported on Form 567. The word "landmark" and the elevations should be given as required above. If in a large structure, a definite part such as a spire or cupola, is recommended as a landmark, it is necessary that the smooth sheet show its position relative to the remainder of the building (see fig. 155).

It is particularly important that the elevations of landmarks be known both above the ground and above mean high water, and the legends must make these elevations clear. They are necessary for the charts and for the Coast Pilot.

### *7845. Ranges, Bearings, and Sailing Lines*

All ranges, bearings for clearing dangers and other purposes, and recommended sailing lines on courses or ranges, shall be shown on the smooth sheet *in pencil* where they have been determined by the hydrographic party, and the following symbols shall be used: A range shall be shown as a broken line of short equal dashes; a bearing shall be shown as a dotted line; and a recommended sailing line shall be shown as a continuous line broken at irregular intervals so as not to be drawn through soundings (see fig. 169). It should be noted that that part of a range line which is to be followed by a vessel is a sailing line and should be so symbolized. The objects which determine the ranges or to which the bearings apply shall be correctly shown and identified, and the names of the objects and the purpose of the range or bearings indicated in pencil along the lines. (See **356**.)

Where a range (indicated by brackets in the Light List) formed by two lights or by two beacons, is located within the limits of the survey, there are specific instructions for the determination of its azimuth by the survey party (see **3833**). Only if the azimuth has been determined by the hydrographic party shall this line be shown on the smooth sheet. The instructions for such locations call for obtaining strong sextant fixes on the range at a sufficient distance from the front range mark to produce a long azimuth line for accurate scaling. In the case of ranges established at an entrance for use in crossing a bar, a sextant fix should be obtained on or outside the bar. These fixes are indexed in the Sounding Records and must be plotted accurately on the smooth sheet. From these plotted positions the ranges are penciled. The azimuths are then scaled by protractor and noted in pencil along the range lines.

### *7846. Overhead Clearances*

Bridge clearances and the clearances of overhead cables are important to navigation and should be shown on the smooth sheet for the information of the chart compiler. They should be left *in pencil* by the field party.

*a. Bridge clearances.*—The vertical and horizontal clearances should be given for all bridges over navigable waters if such information has been obtained (see **3836**). Where a discrepancy exists between the field data and the data given in the "List of Bridges Over the Navigable Waters of the United States," published by the United States Corps of Engineers, the field data should be given on the smooth sheet, but attention should be called to the discrepancy in the Descriptive Report (see **842*P***). The notation on the smooth sheet should include the name of the bridge, if it has one; the type of bridge, whether fixed, draw, etc.; the horizontal clearance in feet; and the vertical clearance in feet above mean high water. The note should be in the form shown in figure 171.

*b. Overhead cables.*—The locations of all overhead cables, transmission, telephone, or telegraph, over navigable waters shall be shown on the smooth sheet by dash pencil lines in a manner that will interfere least with the plotted soundings. The note on the smooth sheet should state "overhead cable" and should give the clearance in feet at mean high water (see fig. 171).

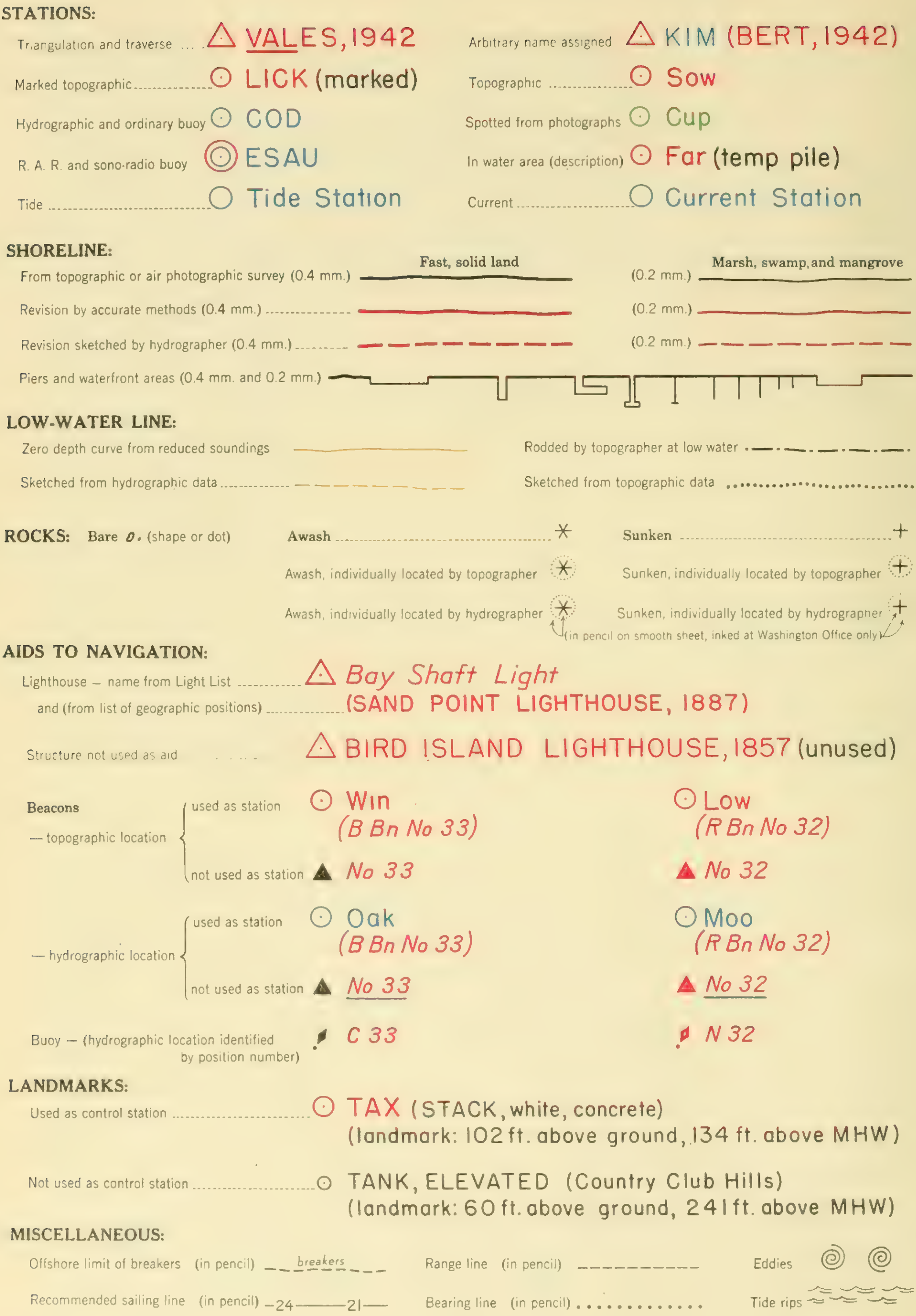



FIGURE 169. — Special symbols for use on hydrographic sheets.
(These are in addition to and are sometimes used instead of those shown in figure 189).

### *7847. Cable Crossings*

The shore ends of submerged cables shall be shown on the smooth sheet by dash pencil lines indicating the general direction of the cable. Each end should be marked "submerged cable" (see fig. 171).

## 785. SYMBOLS FOR SMOOTH SHEET

The symbols to be used on the smooth sheet are generally those used on the charts which are illustrated in figure 189. It is not necessary that the symbols on the smooth sheet be as perfect as those on the charts, nor that the drafting be as artistic (see **721**). Slight modifications in the direction of simplicity may be made, the important thing being that they convey the information neatly and unmistakably.

There are certain exceptions to the use of chart symbols for smooth sheets, and these have been discussed in detail in preceding paragraphs. Examples of this divergence are the depth curves, which are shown in color on the smooth sheet but are symbolized on the charts; and lights and beacons which are almost invariably shown by their station symbols rather than by the chart symbols.

Figure 169 illustrates the symbols and lettering to be used on the smooth sheet, which differ from the symbols used on the published charts.

## 786. MISCELLANEOUS DATA

In addition to those mentioned heretofore, as many of the following details as have been obtained by the field party shall be shown on the smooth sheet. They should be left in pencil unless otherwise noted, to be subsequently inked at the Washington Office after verification.

### *7861. Tide Rips*

These occur in places where strong currents are found and are usually encountered in the vicinity of shoals or where the bottom is uneven. A knowledge of these is of importance to the mariner and they should be shown on the smooth sheet either by legend or by symbol and legend, and qualified as heavy, moderate, or light. Where the feature is extensive, the approximate limits should be outlined and an appropriate descriptive note added.

### *7862. Breakers and Shoal Areas*

The limits of breakers, whether offshore or alongshore, should be shown by a dash line with the notation "breakers" added. Where cuts are taken to single breaks, their intersection should be indicated by the sunken-rock or rock-awash symbol, as the case may be. If there are no rocks, the spot should be encircled with a broken line enclosing the word "breakers".

Shoal areas covered at the sounding datum, over which sounding lines have not been run, should be outlined with a dash line within which the estimated depth is inserted.

The low-water limits of shoals, bars, mud flats, sand banks, etc., that bare at the sounding datum but which have not been accurately surveyed, should be taken from the best available source and shown on the smooth sheet in accordance with **754**. The estimated height above the sounding datum should be given if available.

### *7863. Marine Vegetation*

The limits of grass and other marine vegetation extending near the surface must be indicated. Wherever a distinctive symbol has been adopted for such vegetation it should be used, except that limits only of extensive beds should be outlined by symbol, the character of the vegetation within being indicated by appropriate legend.

The symbol for grass or any other land vegetation should not be used to represent marine growth. If the bottom is grassy, the standard bottom characteristic abbreviation for grass should be used.

### *7864. Kelp*

Kelp is one of the most important of the seaweeds encountered on a hydrographic survey and should be indicated on the smooth sheet wherever located. One of its principal characteristics is that it generally grows in rocky bottom and for that reason its presence indicates a possible danger. This is particularly true in Alaska where the only indication of many submerged pinnacle rocks may be a strand or two of kelp. In exposed waters kelp may grow in depths of 9 or 10 fathoms and in protected waters it may grow in even greater depths. Dead detached kelp should not be confused with live kelp attached to rocks; the former floats on the water in masses, while the latter streams away level with the surface. (See also **3623*b***.)

Kelp should be shown by symbol where the patch is a small one. Only the limits of extensive beds need be delineated by symbol, the remainder being indicated by appropriate legend. Where the kelp is towed under at certain stages of the tide such information should be added to the smooth sheet.

### *7865. Tide and Current Stations*

The locations of all tide and current stations shall be shown on the smooth sheet by blue circles, slightly larger than a hydrographic station symbol, accompanied by the name "Tide Station" or "Current Station" lettered in blue.

### *7866. Wire-Drag Finds and Clearance Depths*

Where a contemporary wire-drag survey has been made, all drag finds, including the bottom characteristics, should be transferred to the hydrographic sheet in green ink and in the same depth unit as the soundings. Where a wire-drag examination has been made to determine the least depth on a shoal or obstruction, the least depth found (if less than that of the hydrographic survey) should be plotted in pencil, and a note with a leader added giving the least depth with position number and day letter, and the clearance depth obtained.

### *7867. Ferry Routes*

Each ferry route should be shown by a single dash line representing the actual route as nearly as it can be determined without sextant angles. Each terminus should be marked "ferry."

### *7868. Wrecks*

Within the area of the survey, wreckage not afloat is located and should be shown on the smooth sheet in accordance with the symbols shown in part "O" of the Symbols and Abbreviations chart (fig. 189, part IX). Wrecks are of two kinds, stranded and

sunken, the former applying where any portion of the hull is above the sounding datum, while the latter applies to those with less than 10 fathoms over them or where the masts only are visible. The topographer, presumably, will have located all stranded wrecks, and these will be transferred from the topographic sheet to the smooth sheet along with the other topographic information. Sunken wrecks are located by the hydrographic party and their positions must be plotted from the data in the Sounding Records. It should be noted that the symbol for a stranded wreck differs from that for a sunken wreck, and that where masts are visible in the latter case, the notation "masts" must be appended to the symbol.

A special symbol is provided for use in showing the depth by which a wreck or other obstruction has been cleared by the wire drag.

Where there are a number of wrecks, or an amount of wreckage, so extensive that the individual items were not located, the outer limit of the dangerous area shall be indicated by a dotted line within which the word "wreckage" is shown.

#### *7869. Obstructions*

A variety of obstructions which may be dangerous to navigation is encountered in hydrographic surveys, all of which must be shown on the smooth sheet. If the obstruction has not been cleared by the wire drag, it is indicated by the least depth obtained by other methods, surrounded by a dotted circle, and accompanied by the word "obstruction" or its abbreviation. If the obstruction has been cleared by the wire drag, a special symbol is provided which shall be used to indicate the safe depth of water over the obstruction (see part "O", Symbols and Abbreviations chart, fig. 189, part IX).

### 787. GEOGRAPHIC NAMES

#### *7871. Authority of the Smooth Sheet*

The hydrographic survey and, therefore, the smooth sheet shall be the authority for all geographic names of hydrographic features, such as channels, sloughs, rivers, inlets, reefs, rocks, shoals, and of topographic features offshore from the high-water line, such as small rocks and islets. Even if the topographer does obtain and verify a portion of these names, the hydrographer is responsible for their correctness and their correct placement on the smooth sheet. In addition to the above names, the names of some of the more prominent topographic features should be added to assist in correlating the hydrographic survey to the land features. (See also section **16**.)

Although not all geographic names may be charted, it is desirable that all features for which there are local names be named on the smooth sheet. These should be distinct names applicable to definite places or areas. Where names are indefinitely applied, it is best not to show them on the smooth sheet, but they should be mentioned in the Descriptive Report. It is incumbent on the smooth-sheet plotter to take extreme care that the names are spelled correctly and that they are applied to the correct features.

#### *7872. Placement of Names*

Geographic names should not be added to the smooth sheet until after the positions and soundings have been plotted. They should be placed so as to indicate clearly and without ambiguity the features designated. Where it is impracticable to place the names closely adjacent to the features, they may be placed some little distance away and connected to the respective features by leaders or arrows.

Geographic names must not obscure nor confuse the soundings. On an inshore hydrographic survey, it is generally necessary to place all the topographic names and many of the hydrographic names inshore from the high-water line. This is especially important in the placement of the names of small streams, sloughs, and inlets. Where names have to be lettered in the water areas, particularly in very congested areas, a judicious placement of the name and spacing of the letters will often avoid obscuring the hydrography. In such cases the lettering may be spread out or closed up as the conditions require.

Geographic names should be oriented on the smooth sheet so as to be read from the south regardless of the direction of the projection on the sheet (see fig. 170). Most names should be lettered in a straight line parallel to the parallels of latitude and, if

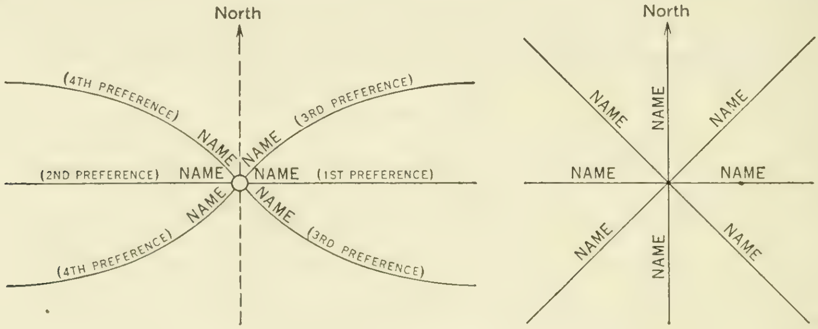



FIGURE 170.—Orientation of names on survey sheets.

practicable, placed immediately east of the feature named. Where it is necessary to place a name on a curve, the beginning or end of the name should be nearly parallel to the parallel of latitude. A name should not be lettered on a reverse curve. Most preferable is a compound curve with the flat part of the curve as nearly as practicable parallel to the parallels of latitude.

If the geographic feature to be named covers a considerable area, as an island or bay, the name should be placed preferably in the approximate center of the area. It should extend across the longest part of the feature and, if practicable, should follow the general curvature of the feature. Such names should never extend beyond the limits or even close to the limits of the feature in question. If the name is composed of several words they should not be too widely separated in order to extend the full length of the feature. Instead the name should be repeated a second, or even a third time.

Where it is necessary to letter a geographic name along a perfectly straight feature, such as a boundary line, railroad, or channel, that does not extend east and west, the following rules should be followed:

(1) Where the direction of the feature is from east of north to west of south, the name should begin at the southern end and extend toward the northern end.

(2) Where the direction of the feature is from west of north to east of south, the name should begin at the northern end and extend toward the southeast.

(3) In the rare case of a feature whose direction is exactly north and south, the beginning of the name should be at the southern end and extend toward the north.

### *7873. Lettering Geographic Names*

All geographic names on the smooth sheet shall be left *in pencil*. They shall be made with single stroke capital letters. The names of the topographic features,

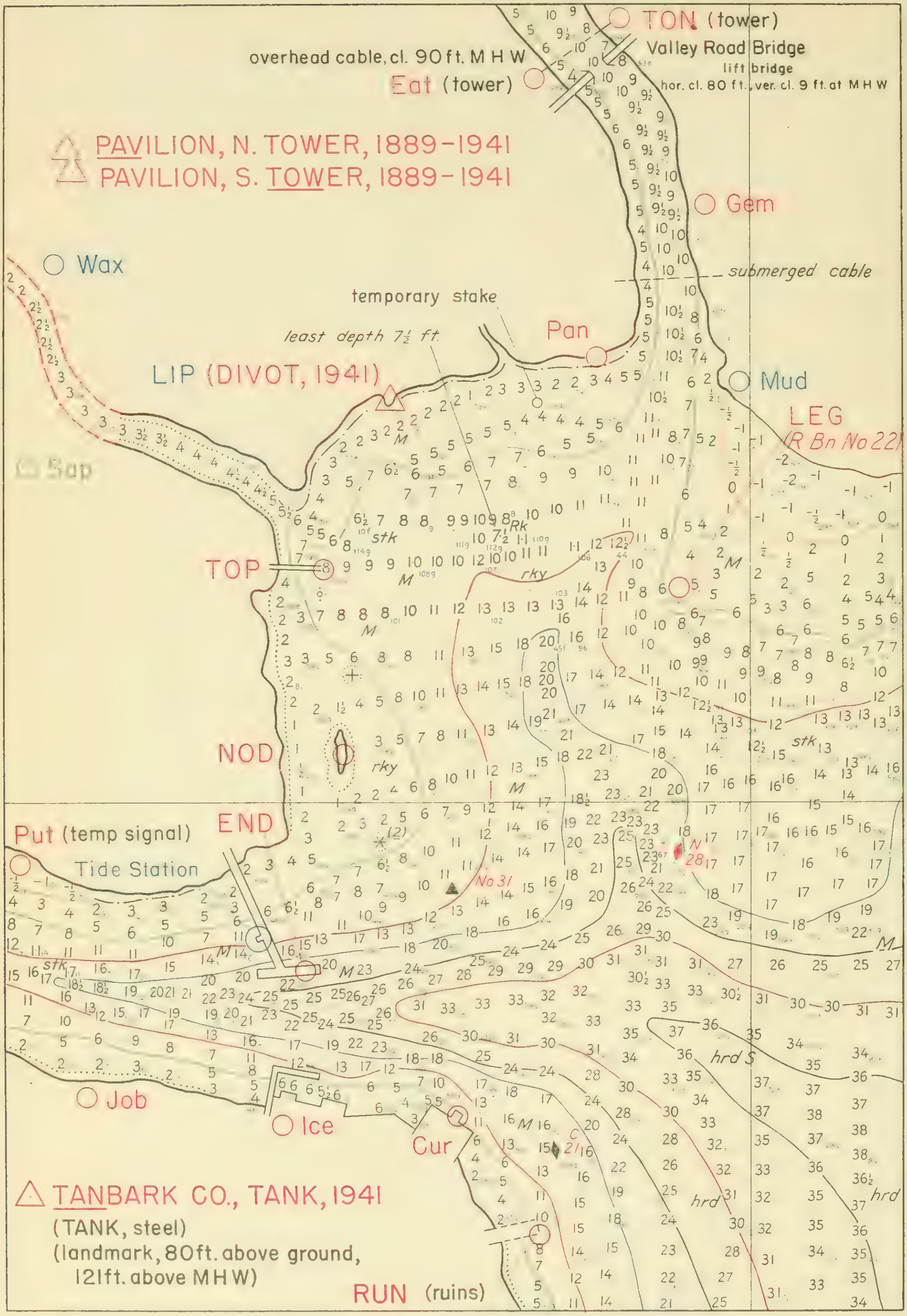



FIGURE 171. Section of completed smooth sheet (reproduced at actual scale)
(The black 24- and 36-foot curves represent pencil lines.)

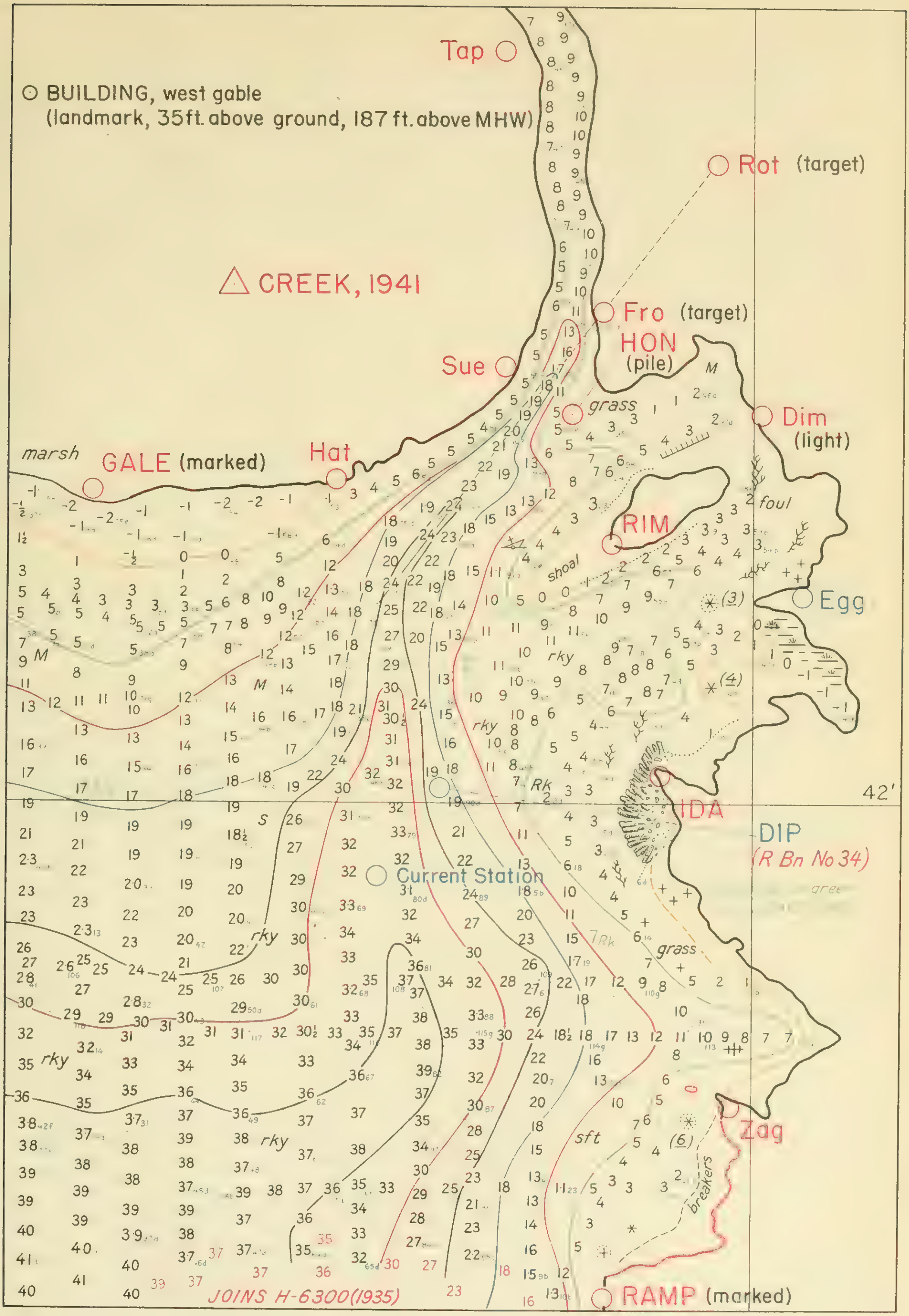



FIGURE 171. Section of completed smooth sheet (reproduced at actual scale).
(The black 24- and 36-foot curves represent pencil lines.)

which in general are the names of everything above mean high water, shall be vertical letters. The names of the hydrographic features, and in general of all features below mean high water, shall be lettered in slanting letters. In the latter classifications are included, of course, shoals, reefs and banks, rocks awash, and sunken rocks.

The names of the most minor features on the smooth sheet shall be lettered in characters 0.1 inch in height and this height shall be increased according to the importance of the feature to a largest permissible height of 0.25 inch. For an equal importance of names it is essential to remember that slanting letters should be slightly smaller than vertical letters because an optical illusion makes the same size of vertical lettering appear slightly smaller.

### *7874. Inking Geographic Names*

Geographic names must never be inked by the field party or by the Processing Office. This is done in the Washington Office after the geographic names have been reviewed and approved (see **9321**). The inking of the geographic names of hydrographic features is often deferred until after the soundings have been verified and inked.

All geographic names are inked in black using a mechanical lettering set.

## 788. LIMITS OF ADJOINING SURVEYS

The limits of adjoining surveys or the overlapping soundings must *not* be shown on the smooth sheet by the field party. (See **3233** and **3256**.) These will be added in the Office at the time of verification. However, it is incumbent on the smooth-sheet plotter to make a comparison with the overlapping soundings on adjoining surveys in order to determine whether *holidays*, or excessive differences exist, and to permit the drawing of the depth curves in the area based on all soundings obtained. The comparison is also necessary as a basis for information required to be included in the Descriptive Report (see **842*J***).

Comparison is best made by tracing the overlapping soundings of one survey and superimposing the tracing on the other. Where adjoining surveys are on different scales, the soundings on the smaller scale should usually be superimposed on the larger scale. The tracings, properly labeled, should be forwarded to the Office with the smooth sheet.

## 79. THE COMPLETED SMOOTH SHEET

The completed smooth sheet shall be considered the authority for the hydrography and for the topographic details within its limits offshore from the high-water line (see **75**). The smooth sheet as submitted by a field party or by a Processing Office should be complete, except that certain portions are left in pencil for inking after verification in the Washington Office (see table 28). After the sheet has been inked and reviewed there should be no necessity for reference to either the Sounding Records or the boat sheet, or to any other records, in order to interpret the data shown thereon. (See fig. 171.) A smooth sheet is, of course, supplemented by information in the Descriptive Report of a nature which cannot be shown easily by graphic means (see section **84**).

The Chief of Party must supervise in a general way the preparation of the smooth sheet to assure himself that it is being done in accordance with standard practice. If the plotting is executed while the party is still on the working ground, he shall take special care to see that any errors, omissions, or discrepancies in the field work are

corrected in the field. On completion of the sheet he shall make a final inspection of the sheet and all the accompanying records and shall report this fact, with his approval (see **7941**).

## 791. Completion of the Smooth Sheet

To assure completeness of the smooth sheet, constant checking is necessary throughout its production. Much of the work done on the sheet is self-checking and it is the duty of the smooth-sheet plotter to check his work as he proceeds. However, certain specific steps mentioned in this Manual do require verification (in the field) by a person other than the plotter (see, for example, **746**).

After the plotter has completed the routine work on the sheet, it must be inspected thoroughly and special attention given to those parts of the work which are not routine, such as comparison with the Sounding Records and the boat sheet (see **7911** and **7912**).

### *7911. Details From Sounding Records*

The completed smooth sheet should depict graphically all the information which has been entered in the Sounding Records. To assure that this has been done, a systematic page by page comparison with the Sounding Records shall be made after completion of all the plotting. Special attention should be given to all entries in the "Remarks" column and to all other entries that are not routine, such as cuts to rocks and aids to navigation, and notes relative to the distance the sounding vessel passes any object. Each detached position should also be verified in order to ensure that it has been plotted and that the correct depth has been shown.

### *7912. Details From Boat Sheet*

The boat sheet often contains supplemental details and notes which are helpful in interpreting the Sounding Records and all of these should be considered in connection with the smooth sheet. Occasionally, the boat sheet is the sole source of rocks, breakers, or kelp, but such information should be used with discrimination. It is incumbent on the plotter at this time either to transfer this data to the smooth sheet or to void it by deletion or by indicating on the boat sheet that it is valueless.

As part of the smooth-sheet inspection, a detailed systematic comparison should be made with the boat sheet, in order to ensure that all essential information has been transferred to the smooth sheet. It is important that hydrographers in the field realize that after review of the smooth sheets in the Washington Office, the boat sheets are retained only a short time before they are disposed of.

### *7913. Importance of Clarity*

It is important that the completed smooth sheet is clear and legible and that no information thereon is indistinct or ambiguous. (See **721**.) The most important features on a smooth sheet are the locations of and least depths on shoals. Before submitting the sheet to the Washington Office, the smooth-sheet plotter should verify these items. The least depth on any shoal should be apparent at a glance without the necessity of a minute inspection of the area, and should be emphasized according to **7753**. If for any reason an important feature is obscured or shown in a manner that there is risk of its being overlooked, a note should be added calling attention to it (see **7914**). Dangers and shoals should be emphasized and it is more important that they be shown with distinction than that a routine symbolization be followed.

### *7914. Use of Leaders*

Explanatory notes are occasionally used on the smooth sheet to avoid possible misinterpretation of the data (see **781**). In order that these may be placed where they will least interfere with the hydrographic data it is often necessary to use a fine leader, or arrow, leading from the note toward the feature to which it refers. Such leaders or arrows are frequently of advantage to emphasize the least depths on shoals (see **7753**).

### *7915. Removal of Temporary Notes*

All temporary pencil notations made on the smooth sheet during the plotting, should be removed before the sheet is transmitted to the Washington Office.

### *7916. Initials of Plotter and Verifier*

During the construction and plotting of a smooth sheet various specific steps are performed. The records must show clearly responsibility for each step, whether it is of plotting or verification. Rubber stamps are provided for this purpose. Stamp No. 42, Hydrographic Survey, is placed in the lower right-hand corner of the smooth sheet and the initials of the plotter and verifier of the phases of work indicated thereon must be appropriately entered (see **746**). Rubber Stamp No. 38, Processing, (fig. 183) is entered in the Sounding Records at the end of each day's hydrography, and the plotter must enter his initials in the appropriate spaces using a pencil of the same color he used to checkmark items in the Sounding Records during the protracting and plotting of the data (see **76** and **773**).

## 792. Schedule of Penciled and Inked Details

For the guidance of the smooth-sheet plotter, table 28 lists the various details that are to be shown in pencil and in ink on the smooth sheet when it is forwarded to the Washington Office. It is to be noted particularly that practically all the topographic information offshore from the high-water line is to be shown in black ink if it originates with the topographic survey and has been verified by the hydrographer, but like information originating with the hydrographic survey is to be left in pencil.

## 793. Registry Numbers and Titles

At the beginning of each field season each survey sheet is assigned a temporary field number by the Chief of Party (see **1541** and **3213**). These field numbers are used for reference purposes during the early part of the season, but are subsequently replaced by permanent registry numbers assigned by the Washington Office. The registry number should be available on completion of the smooth sheet, and if so, this number should be shown in pencil on the back of the sheet in the middle of each end, with the corresponding field number just above it. The registry number should be used in referring to the smooth sheet or to any of the records pertaining thereto, after it is available. (See **1542** and **1543**.)

After the smooth sheet is received in the Washington Office and registered, it becomes a part of the permanent archives, and thereafter is never taken from the Washington Office.

TABLE 28.—*Schedule of penciled and inked details*

| Pencil | Black ink | Various colored ink |
|---|---|---|
| Registry number. | Projection lines. | Position numbers. |
| Soundings. | Projection numerals. | Day letters. |
| Bottom characteristics. | Datum note. | Position dots. |
| Geographic names. | Geographic position of reference triangulation station. | Station names. |
| Sailing lines. | High-water line. | Station symbols. |
| Notes concerning rocks, least depths, etc. | Large buildings. | Tide gage locations. |
| Tide rips. | Landmarks (symbol, name, elevation). | Current station locations. |
| Swirls. | Notes in land area. | Survey buoy symbols. |
| Marine vegetation (in general). | | R.A.R. distance circles. |
| Ranges and bearings. | **From topographic survey:* | R.A.R. distance arcs. |
| Depth curves. | Rocks (bare, awash, or sunken). | Navigational aids. |
| Low-water line. | Reefs. | Shoreline by hydrographer. |
| Lines connecting positions. | Ledges. | Bare rock elevations by topographer. |
| Light sectors. | Wreckage. | |
| Leaders or arrows in sounded area. | Breakers. | |
| Notes in sounded area. | Limiting danger lines. | |
| Adjustments between topographic and hydrographic data. | Foul areas. | |
| Ferry routes. | Kelp. | |
| Submerged cables. | Fish stakes. | |
| | Spoil areas. | |
| **From hydrographic survey:* | | |
| Rocks (bare, awash, or sunken). | | |
| Reefs. | | |
| Ledges. | | |
| Wreckage. | | |
| Breakers. | | |
| Limiting danger lines. | | |
| Foul areas. | | |
| Kelp. | | |
| Fish stakes. | | |
| Spoil areas. | | |
| Bare rock elevations. | | |

*These features, if they originate with the hydrographic survey, are to be left in pencil on the smooth sheet, when transmitted to the Washington Office; if such data originate with the topographic survey and are verified by the hydrographic survey, they are to be inked in black ink.

The title of the hydrographic survey must *not* be penciled or inked on the smooth sheet by the field party. This is accomplished in the Washington Office. However, the information necessary for the title is reported on Form 537, Hydrographic Title Sheet (see **8412**).

## 794. Final Inspection

After completion of the smooth sheet the plotter should inspect the entire work thoroughly to make sure there are no errors, omissions, or discrepancies, and that the style and appearance conform to the standards prescribed in chapter 7. He should also assure himself that all temporary notes have been removed (see **7915**) and that the initials of the plotter and verifier have been appropriately entered on the smooth sheet and in the Sounding Records in the stamps provided for that purpose (see **7916**).

If the hydrographer who was in actual charge of the field operations can do so, he shall inspect the smooth sheet and make a thorough comparison with the boat sheet, to assure himself that the smooth sheet is complete and accurate, and that it delineates clearly the results of his field survey. Because of his intimate knowledge of the area, it is always possible that his inspection may disclose an erroneous interpretation made by the plotter. This is particularly true in the case of rocks, shoals, breakers, and so forth, for which the information in the Sounding Records is sometimes inadequate or ambiguous.

### *7941. Final Inspection by Chief of Party*

After the completion of the smooth sheet, and before it is transmitted to the Washington Office, the Chief of Party shall inspect the sheet and all of the records. He shall also furnish on a separate sheet of paper as part of the Descriptive Report a statement to the effect that the sheet and accompanying records have been inspected by him, and are approved. (See **8437**.)

## 795. Principal Deficiencies of Smooth Sheets

In the past, hydrographic smooth sheets received in the Washington Office, have occasionally been found deficient in various respects, and to assist in eliminating these in the future a list of principal deficiencies is furnished herewith. This is not intended as a complete list of all of the deficiencies, but it does contain those which cause most trouble during the verification and review.

(*a*) Positions have been incorrectly plotted due to the use of a protractor out of adjustment.

(*b*) Incorrect spacing of soundings; omission of soundings from a failure to utilize properly the space available; insertion of soundings not recorded in the Sounding Record.

(*c*) Omission of too large a percentage of the recorded bottom characteristics.

(*d*) Excessive size or careless lettering of position numbers and day letters; very infrequently making their size too small; careless placing of them.

(*e*) Positions plotted with angles differing from those in the Sounding Record with no correction or note having been made in the Record.

(*f*) Certain notes in the Sounding Records have been ignored.

(*g*) Soundings penciled in a straight line between positions where the vessel followed a curved path.

(*h*) Limits and numbers of adjoining sheets shown in ink (these should be omitted entirely).

(*i*) Geographic names inked (these should be left in pencil).

(*j*) Failure to check and investigate depths which appear erroneous, or excessive differences at crossings.

(*k*) Inaccurate transfer of the shoreline from the topographic survey.

(*l*) Failure to have some of the operations checked, or failure to enter in the place provided the initials of the person performing or checking the operation.

(*m*) The use of too hard a pencil.

(*n*) The omission of a reference triangulation station and the geographic datum.

(*o*) The omission of the minus sign from soundings above the sounding datum; the low-water line incorrectly drawn with reference to the half-foot soundings above and below the sounding datum.

(*p*) The omission of important notes which appear only on the boat sheet, having been omitted from the Sounding Record.

(*q*) Inking the low-water line (this should be in pencil).

## 796. Shipment to Washington Office

Completed smooth sheets shall be shipped to the Washington Office only in special metal or heavy cardboard tubes, which may be obtained on requisition. For shipment, smooth sheets shall never be rolled to a diameter smaller than 4 inches, and shall be forwarded by registered parcel post or express. The boat sheet shall be shipped separately. (See also **836**.)

Each smooth-sheet shipment shall be accompanied by a copy of the transmitting letter (Form 413), on which it is listed, the original being forwarded under separate cover.

# CHAPTER 8. RECORDS AND REPORTS

The importance of clear and comprehensive records and reports of a hydrographic survey cannot be overemphasized, for the value of a survey, no matter how complete and satisfactory the field work may be, is impaired if the records and reports are incomplete, unintelligible, or inadequate in any respect. Satisfactory records can be obtained only by the exercise of good judgment and constant attention and care on the part of all concerned.

With the complexity of modern hydrographic surveying the number of necessary records and reports has increased; it is no longer possible nor desirable to confine these to Sounding Records and a Descriptive Report. It is incumbent on the Chief of Party to see that the records are arranged in the most convenient manner for all concerned, that *all* necessary records and reports are submitted, and that they are appropriately cross-referenced for easy reference and complete understanding and intelligibility. All records and reports which pertain to one hydrographic sheet, and one only, should bear clearly the registry number of that survey. (See **154**.) All records and reports submitted on a seasonal basis, or any other basis so that they are applicable to more than one hydrographic survey, should bear the registry numbers of all of the surveys to which they are applicable; and the Descriptive Report accompanying each survey should refer to all of the special, seasonal, or other records and reports which contain any data which are pertinent.

## 81. SOUNDING RECORD

The Sounding Record (Form 275) is the most important record connected with a hydrographic survey. It is the official record of the soundings, and generally of the position data. It should be complete and self-explanatory. From it, sometimes supplemented by accompanying records, it should be possible, without difficulty or doubt, to replot the hydrographic sheet at any future date. All entries and notes should be clearly understandable at any future date, when perhaps radically different methods will be in use.

Form 275, Soundings, is the basic record book for all hydrographic surveys, except wire-drag surveys which are recorded in Form 411, Wire Drag, and deep-sea wire soundings which are recorded in Form 376, Soundings with Wire. Under certain conditions, another form of Sounding Record may be used (see **817**). Generally the same volume shall contain the complete record of time, depth, position data, and miscellaneous entries and notes; although at times, when it is more convenient to do so, the position data may be recorded as a separate record. In Radio Acoustic Ranging (R.A. R.) the part of the position data consisting of the time intervals and R.A.R. distances is always recorded in a separate book, the Bomb Record (see **8311**).

The sounding of each hydrographic survey unit shall be recorded chronologically in a separate series of volumes (temporarily consecutively numbered) for each hydrographic sheet. Under no circumstances shall hydrography to be plotted on two or more hydrographic sheets be intentionally recorded in the same volume.

465382—44——49

If more than one hydrographic survey unit surveys in an area covered by a single sheet, a temporary series of numbers shall be used by each unit that uses more than one volume; except that a small amount of sounding, such as the development of a shoal

Form 275 — Locality: S. E. ALASKA — Sublocality: *Katroon Bay* — 71

SOUNDINGS

Year 19 — Month — OCT 18 1941 — Day of Month — Boat used — LAUNCH NO. 2 — ; *e* day

| POSITION NUMBER | TIME Mer. 135 ... M | SOUNDINGS Feet (~~Fathoms~~) | SOUNDINGS Tenths (~~Feet~~) | CORRECTIONS Lead Line (~~Tubes~~ ~~Echo~~) Feet (~~Fathoms~~) | CORRECTIONS Slope Factor Fathoms | CORRECTIONS Red. for Tide Feet (~~Fathoms~~) | REDUCED SOUNDINGS Field Feet (~~Fathoms~~) | REDUCED SOUNDINGS Field Tenths (~~Feet~~) | REDUCED SOUNDINGS Office Feet (~~Fathoms~~) | REDUCED SOUNDINGS Office Tenths (~~Feet~~) | | BOTTOM | HEADING BY boat COMPASS | ANGLES AND RANGES BEARINGS LOG READINGS ENGINE REVOLUTIONS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h m s 09:55 30 | 3 | 5 | 0 | | -5 2 | -1 | 7 | | | | | 130 | | |
| | 45 | 3 | 0 | | | | -2 | 2 | | | | | | | |
| | | | | | | | | | | | | | | | |
| <37 | 56 00 | 2 | 5 | | | | -2 | 7 | | | | rky | | <37 Tax 76 31 | Only one < available. See |
| | | | | | | | | | | | | | | Ban | B.S. Line ends 30m. |
| | | | | | | | | | | | | | | ~~Fig~~ | off shingle beach. |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| < 38 | 09:58:45 | 3 | 0 | | | -5.0 | -2 | 0 | | | | rky | 325 | < 38 Ban 73 42 | Line begins 25m. |
| | | | | | | | | | | | | | | Fig | SE. of rock bare 2 ft. |
| | 09:59:00 | 3 | 5 | | | | -1 | 5 | | | | | | Nub 46 33 | L Savage - leadsman |
| | 15 | 5 | 0 | | | | 0 | 0 | | | | | | | |
| | 30 | 7 | 0 | | | | 2 | 0 | | | | | | | |
| | 45 | 6 | ok 4 | | | | 1 | 4 | | | | | | | Ver. by leadsman |
| <39 | 10:00:00 | 10 | 0 | | | | 5 | 0 | | | | | | <39 Ban 67 15 | |
| | | | | | | | | | | | | | | Fig | |
| | 20 | 13 | 0 | | | | 8 | 0 | | | | bk S | | Out 41 08 | |
| | 40 | 19 | 0 | | | | 14 | 0 | | | | | 327 | | |
| | 01:00 | 25 | 5 | | | | 20 | 5 | | | | | | | * change sounding interval |
| | 30* | 29 | 5 | | | | 24 | 5 | | | | | | | |
| | 02:00 | 33 | 5 | | | | 28 | 5 | | | | | | | |
| | 30 | 38 | 5 | | | | 33 | 5 | | | | | | | |
| | | | | | | | | | | | | | | | |
| < 40 | 03:00 | 42 | 0 | | | | 37 | 0 | | | | | | <40 59 32 | Reduce speed |
| | | | | | | | | | | | | | | S | |
| | 40 | ~~4~~ 6 | 5* | | | | 41 | 5 | | | | | | 36 22 | *cor. by leadsman at once. |
| | 04 20 | 53 | 5 | | | | 48 | 5 | | | | bk S | | Fig - Lug 89 03 | |
| | 05 00 | 57 | 0+ | | | | 52 | 0 | | | | | | | +Kelp 20m. to port. |
| | 40 | 62 | 0 | | | | 57 | 0 | | | | | | | |
| < 41 | 06.20 | 66 | 0 | | | | 61 | 0 | | | | | 324 | < 41 54 40 | F.S. for wire |
| | | Fathoms | Tenths | | | Fathoms | Fathoms | Tenths | | | | | | S | soundings. Sheave No. 136 |
| | | | | | | | | | | | | | | 31 57 | (Note changed units) |
| st | 40 | 14 | 5 | 0 | | 0.8 | 13 | 7 | 82 | — | | | | | |
| ah | 07:05 | | | | | | | | | | | | | | |
| st | 25 | 18 | 0 | | | | 17 | 2 | 103 | — | | | | | |
| ah | 50 | | | | | | | | | | | | | | |
| <42 st | 08:10 | 19 | 5 | | | | 18 | 7 | 112 | — | | wh S. bk Sp. | | <42 Ban ~~50~~ 49 06 | cor. immediately |
| | | | | | | | | | | | | | | Fig | |
| ah | 40 | | | | | | | | | | | | | Gag ~~Nag~~ 47 10 | |
| st | 09:00 | 22 | 0* | | | | 21 | 2 | 127 | — | | | | | *Wire leading about 15° aft. |

FIGURE 172.—Record of handlead and wire soundings—sextant fixes. (Double page of Sounding Record reduced about one-half.)

by a launch in an area surveyed by a ship, may be recorded in a ship volume, if more convenient.

The record must be unmistakably legible. Fine lettering is not required, neither is it necessary to print in making entries, but it is essential that every numeral, abbrevia-

tion, and word be clear beyond any doubt. The work must be recorded in a systematic manner and, insofar as possible, in the form prescribed in this Manual. A 3H pencil is usually preferable for recording, although in damp weather a 2H sometimes gives better results.

Form 275 — Locality: SOUNDINGS GULF OF MAINE — Sublocality: Downeast Bay — 59

Year 19 — Month JUL 10 1942 — Day of Month — Boat used COWIE ; K day

| POSITION NUMBER | TIME MER. 60 ..... M. | SOUNDINGS FEET ~~FATHOMS~~ | SOUNDINGS TENTHS ~~FEET~~ | CORRECTIONS ~~LEAD~~ ~~LINE~~ ~~TUBES~~ ECHO FEET ~~FATHOMS~~ | CORRECTIONS ~~SLOPE~~ ~~FACTOR~~ FATHOMS | CORRECTIONS RED. FOR TIDE FEET ~~FATHOMS~~ | REDUCED SOUNDINGS FIELD FEET ~~FATHOMS~~ | REDUCED SOUNDINGS FIELD TENTHS ~~FEET~~ | REDUCED SOUNDINGS OFFICE FEET FATHOMS | REDUCED SOUNDINGS OFFICE TENTHS FEET | | BOTTOM | HEADING BY Steering COMPASS | ANGLES AND RANGES BEARINGS LOG READINGS ENGINE REVOLUTIONS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. 12:02:20 | 53 | 2 | +0.4 | | -10.6 ✓ | 43 | 0 | | | | | 87 | | B scale |
| | 40 | 57 | 6 | 0.6 | | | 47 | 6 | | | | | | | |
| | 03:00 | 59 | 6 | | | | 49 | 6 | | | | | | | |
| <84 | 20 | 61 | 2 | | | | 51 | 2 | | | | hrd S | | <84 New 80 50 | L.E. for lunch |
| | | | | | | | | ✓ | | | | | | Cow | Drifting |
| | | | | | | | | | | | | | | Gap 56 31 | Angles reversed |
| | | | | | | | | | | | | No. 35 | | BAR CHECK | |
| | | | | | | | | | | | | | | ~~FATHOMETER COMPARISON~~ | Index set correct |
| | | | | | | | | | | | | | | ~~LEADLINE COMPARISON~~ | at 2 ft |
| | | | | | | | | | | | | Mark or Fath. reading M | | True length or depth D — Correction D-M | Gain control set |
| | | | | | | | | | | | | | | feet | at 8.5 (normal) |
| | | | | | | | | | | | | 10 | | 10 0 | A scale |
| | | | | | | | | | | | | 20 | | 20 0 | |
| | | | | | | | | | | | | 29.9 | | 30 + 0.1 | |
| | | | | | | | | | | | | 39.9 | | 40 + 0.1 | |
| | | | | | | | | | | | | 39.7 | | 40 + 0.3 | B scale |
| | | | | | | | | | | | | 49.8 | | 50 + 0.2 | A " |
| | | | | | | | | | | | | 49.6 | | 50 + 0.4 | B scale |
| | | | | | | | | | | | | 59.4 | | 60 + 0.6 | |
| | | | | | | | | | | | | 69.2 | | 70 + 0.8 | |
| | | | | | | | | | | | | | | | Ran to tend tide gage at |
| | | | | | | | | | | | | | | | Shelter Cove. Extra dist. |
| | | | | | | | | | | | | | | | run 5.3 naut. mi. |
| | | | | | | ✓ | | | | | | | | | |
| <85 | 13:15:00 | 16 | 6 | 0 | | -8.8 | 7 | 8 | | | | | 183 | <85 New 37 04 | No. 39 LINE BEGINS |
| | | | | | | | | | | | | | | Jam | Lat 43°45.8' Long 70°05.4' |
| | 20 | 18 | 8 | | | | 10 | 0 | | | | | | Sap 77 06 | A scale |
| | 40 | 19 | 6* | | | | 10 | 8 | | | | | | | * Rock awash ~~00~~ Jam, |
| | 16:00 | 20 | 6 | | | | 11 | 8 | | | | | | | dist. approx. 1/4 mi. |
| | 20 | 21 | 0 | | | | 12 | 2 | | | | | | | |
| | 30 | 19 | 5* | | | | 10 | 7 | | | | | | | * Extra sounding |
| | 40 | 23 | 6 | | | | 14 | 8 | | | | | | | |
| | | | | | | | | | | | | | | | |
| <86 | 17:00+ | 22 | 6 | | | | 13 | 8 | | | | | | <86 Rut New 53 57 | Split angle |
| | | | | | | | | | | | | | | ~~Jam~~ | + Fix 5 sec. late |
| | 20 | 23 | 4 | | | | 14 | 6 | | | | | | Jam-Sap 69 24 | |
| | 40 | 24 | 4 | | | | ~~16~~ 15 | 6 | | | | | | | |
| | 18:00 | 23 | 6 | | | 8.6 ✓ | 15 | 0 | | | | | | | |
| | 20 | 21 | 8 | | | | 13 | 2 | | | | | | | |
| | 40 | 22 | 4 | | | | 13 | 8 | | | | | | | |
| | | | | | | | | ✓ | | | | | | | |

FIGURE 173.—Record of echo soundings—sextant fixes. (Double page of Sounding Record reduced about one-half.)

The record book should be protected while in use by a paper or oilcloth cover.

A Sounding Record is essentially a time record of a recurring series of acts and events, with the occasional interspersion of related material. The record must clearly

show the relationship between these acts and their recorded times. Generally each entry should appear on the same horizontal line with its respective time, but occasionally, miscellaneous notes and entries may be made at other places and referred to their corresponding times by distinctive reference marks.

Form 275

SOUNDINGS — *Locality* APPROACHES TO NEW YORK — *Sublocality* So. of Long Island — 56

*Year 19* — *Month* SEPT 15 1940 — *Day of Month* — *Boat used* OCEANOGRAPHER ; GA *day*

| POSITION NUMBER | TIME MER 60 M. | SOUNDINGS ~~FEET~~ FATHOMS | SOUNDINGS TENTHS ~~FEET~~ | CORRECTIONS ~~LEAD LINE~~ ~~TUBES~~ ECHO ~~FEET~~ FATHOMS | CORRECTIONS ~~SLOPE~~ ~~FACTOR~~ FATHOMS | CORRECTIONS RED. FOR TIDE ~~FEET~~ FATHOMS | REDUCED SOUNDINGS FIELD ~~FEET~~ FATHOMS | REDUCED SOUNDINGS FIELD TENTHS ~~FEET~~ | REDUCED SOUNDINGS OFFICE FEET FATHOMS | REDUCED SOUNDINGS OFFICE TENTHS FEET | | BOTTOM | HEADING BY Gyro. COMPASS | ANGLES AND RANGES BEARINGS LOG READINGS ENGINE REVOLUTIONS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h. m. s.<br>17:52:30 | 69 | 0 | -0.2 | | -0.8 | 68 | 0 | | | | | 87 | | |
| | 53:00 | 69 | 0 | | | | 68 | 0 | | | | | | No. 24<br>Position No 103 b<br>Log 98.85<br>R C | |
| | 30 | 69 | 0 | | | | 68 | 0 | | | | | | | See Bomb Record |
| <103b | 54:00 | 69 | 5 | | | | 68 | 5 | | | | | | | L.T.R. |
| | | | | | | | | | | | | | | | |
| | 30 | 69 | 5 | | | | 68 | 5 | | | | | | No. 32 | PERSONNEL |
| | 55:00 | 70 | 0 | | | | 69 | 0 | | | | | | In charge J. A. Smith | Cdr. |
| | 30 | 71 | 5 | | | | 70 | 0 | | | | | | Plotter J. A. S. | Protractor No. |
| | 56:00 | 75 | 5 | | | | 74 | 5 | | | | | | L. Angle<br>R Angle | Sextant No.<br>Sextant No. |
| <104 | 30 | 79 | 0 | | | | 78 | 0 | | | | | 183 | Recorder F. Ingram<br>At chronograph D. Ackland | Clock No. H 155 O.K.<br>At fathometer R.B. Marsh |
| | 57:00 | 81 | 0 | | | | 80 | 0 | | | | | | At sounding mach. | Leadsman |
| | 30 | 84 | 0 | | | | 83 | 0 | | | | | | <104 log 99.23 | O. C. |
| | 58:00 | 87 | 0 | | | | 86 | 0 | | | | | | | |
| | 30 | 90 | 5 | | | | 89 | 5 | | | | | | | |
| | | | | | | | | | | | | | | | |
| <105 | 59:00 | 94 | 0 | | | 1.0 | 92 | 8 | | | | | | No. 24<br>Position No 105<br>Log 99.23<br>R C | Bomb missfired |
| | | | | | | | | | | | | | | | |
| | 30 | 97 | 5 | | | | 96 | 5 | | | | | | | |
| | 18 00:00 | 100 | 5 | 0 | | | 99 | 5 | | | | | | | |
| <106 b | 15 | 103 | – | | | | 102 | – | | | | | | No. 24<br>Position No 106 b<br>Log 99.61<br>R C | |
| | | | | | | | | | | | | | | | |
| | 30 | 106 | – | | | | 105 | – | | | | | | | |
| | 01:00 | 109 | – | | | | 108 | – | | | | | | | |
| | 30 | 111 | – | | | | 110 | – | | | | | | No. 36<br>Sextants | Clock |
| | 02:00 | 113 | – | | | | 112 | – | | | | | | Sounding records inspected:<br>James N. Jones | Officer in charge |
| | 30 | 116 | – | | | | 115 | – | | | | | | | Chief of party |
| | 03:00 | 118 | – | | | | 117 | – | | | | | | | |
| <107 | 30 | 120 | – | | | | 119 | – | | | | | | <107 log 00.19 | L.T.L. Begin S-turn |
| | | | | | | | | | | | | | | | |
| <108 | 04:00 | 122 | – | | | | 121 | – | | | | | 160 | <108 log 00.27 | O. C. |
| | 30 | 123 | – | | | | 122 | – | | | | | | | |
| <109 | 45 | | | | | | | | | | | | | <109 log 00.37 | L.T.R. |
| | | | | | | | | | | | | | | | |
| | 05:00 | 124 | – | | | | 123 | – | | | | | | | |
| <110 b | 30 | 126 | – | -0.5 | | | 124 | 5 | | | | | 179 | No 24<br>Position No 110 b<br>Log 00.47<br>R C | O. C. |
| | | | | | | | | | | | | | | | |
| | 06:00 | 126 | – | | | | 124 | 5 | | | | | | | |
| | 30 | 127 | – | | | | 125 | 5 | | | | | | | |
| <111 | 07:00 | 129 | – | | | | 127 | 5 | | | | | | <111 log 00.66 | Fog. Speed reduced |
| | | | | | | | | | | | | | | | Fog signals started |

FIGURE 174.—Record of echo soundings—R.A.R. control. (Double page of Sounding Record reduced about one-half.)

The approved manner of recording handlead, wire, and echo soundings controlled by three-point fixes is shown in figures 172 and 173; and that for echo sounding controlled by R.A.R. in figure 174. In these figures the limited space available has been

conserved as much as possible. In recording hydrography, while space should not be wasted, no attempt should be made to save it by crowding the positions and other data. In some cases it may be necessary to leave a number of blank spaces between soundings in order to provide plenty of room for position data, explanatory notes, etc.

Recorded data shall *never* be erased; all corrections shall be made by crossing out the incorrect entry and making the correct one directly above or to one side, where it cannot be misinterpreted. Entries which are rejected as erroneous shall be indicated by an **R** written boldly over the entry.

Rubber stamps are provided and must be used for recording nearly all the information required at the beginning and end of the day's work and for many of the changes during the day. (See **813** and **816**.)

To facilitate plotting soundings on the boat sheet a carbon copy of that part of each page of the Sounding Record including position numbers, time, and soundings is sometimes made on a long narrow strip of paper. This is held temporarily in place with paper clips during the recording, and as each record page is completed the carbon copy is given to the boat-sheet plotter.

### 811. RECORDER'S DUTIES

The recorder keeps the official written record and notes of the hydrographic survey in the Sounding Record, with a few exceptions. A competent recorder must be thorough, conscientious, accurate, and not easily rattled by confusion; and he must be thoroughly familiar with all phases of sounding and with the requirements of this Manual. His principal duties are described in **3414**.

The importance of the duties of the recorder cannot be overemphasized, for it is his record that contains practically the entire data of the survey, and any error, omission, or ambiguity will almost certainly cause confusion in the subsequent plotting and verification of the work and may be the cause of a large amount of unnecessary field work.

The recorder must be certain that he hears and records all data correctly and that the record is complete and in accordance with the requirements of this Manual. He should repeat all soundings, angles, and other data as he records them and must not hesitate to ask for repetition when necessary; he should be particularly careful to distinguish 7's from 11's, and other confusing numbers (see **4623**). The recorder should instantly note any unusual occurrences or improbable data and should immediately request verification, or report them to the officer-in-charge. An unusual or improbable sounding should be checked immediately, and he should usually detect a gross blunder in a sextant reading, or an impossible fix. Data which are confirmed should be marked with a checkmark (√) or with an "O.K."

The recorder should strive to make the record neat and must make it, without question, legible. He should never make an erasure, but cross out the incorrect entry. Even after a survey has been verified, the Records may be referred to numerous times and unless they are kept in a clear and intelligible manner their value in later years will be greatly diminished.

The recorder is responsible for checking the leadline and recording the results in accordance with **4622**. Rubber Stamp No. 35, Leadline Comparison, shall always be used for this purpose. (See also **3414** and fig. 178.)

### *8111. Standard Abbreviations*

Because of the vast amount of recording and the speed which is often required, abbreviations for many of the terms and expressions which are used repeatedly are advantageous. The list which appears here is to be considered standard. This does not preclude the use of common well-known abbreviations which may not be included. If the need arises for an unusual abbreviation for a term used repeatedly, but not included in the list, it should be explained in the front of sounding volume No. 1 of each sheet for which it is used.

Abbreviations for bottom characteristics are given in part "S" of the Symbols and Abbreviations chart (fig. 189).

| *abbreviation* | *term* |
|---|---|
| $\frac{o}{18}$ | no bottom (at 18) |
| $<$ | angle |
| ⊙ | station |
| θθ | in range or on range |
| ah | ahead |
| B. S. | boat sheet |
| c/c | changed course |
| cor | correction |
| dist | distance |
| D. R. | dead reckoning |
| fath | fathometer |
| fm | fathom |
| F. S. | full speed |
| H. L. | handlead |
| H. S. | half speed |
| hyd | hydrography |
| L$<$ | left angle |
| Lat. or $\Phi$ | latitude |
| L. B. | line begins |
| L. E. | line ends |
| L. L. | leadline |
| Long. or $\lambda$ | longitude |
| L. T. | line turns |
| L. T. L. | line turns left |
| L. T. R. | line turns right |
| M | missed sounding |
| N. G. | no good |
| N. P. | not plotted |
| N. R. | no return (R.A.R.) |
| obj | object |
| o/c | on course |
| pos | position |
| p. s. c. | per standard compass |
| R | rejected |
| Ṙ$<$ | right angle |
| R.A.R. | Radio Acoustic Ranging |
| R. C. | revolution counter |
| r. p. m. | revolutions per minute |
| S | same |
| sdg | sounding |
| Sl. S. | slow speed |
| S. R. B. | sono-radio buoy |
| st | stop |
| stbd | starboard |
| St. S. | standard speed |
| T | true (bearing) |
| T. W. | Taut wire |
| V. C. | vertical cast |
| W. D. | wire drag |

## 812. PAGE HEADINGS

The appropriate entries shall be made in full in the spaces at the top of the first and last record page of a day's work and, if it is divided between two volumes, on the last page of the first and the first page of the second volume. The entries should be made on each page if this does not preclude the proper recording of more vital information. A dating stamp and rubber stamps with the vessel's name and the general locality may be used to enter these data after the completion of the day's work, but under no circumstances should such information be stamped on pages in advance of the recording.

### *8121. Day Letter*

For proper identification, each day's work of each vessel shall be assigned a letter in alphabetical order (beginning with the letter *A* and omitting *I* and *O*), such letter to be entered in color in the appropriate space at the top of each record page. The survey ship and each smaller unit shall have a separate series, distinguishing them by using capital letters of one color for the ship and lower-case letters and a different color for each other vessel—these distinctions to be preserved in the records and on the sheets. Two small boats used by the same hydrographic survey unit on the same day need not be distinguished. See **3311** for special cases when sounding is continued past midnight.

When the alphabet is exhausted, double letters should be used in accordance with **3311**. For colors, blue, purple, green, and red should be given preference in the order named. Yellow and black shall not be used.

### 813. INFORMATION AT BEGINNING OF DAY'S WORK

Certain information relative to personnel engaged, instruments used and their adjustments, and other pertinent facts, which are important to a proper understanding and application of the records, shall be entered at the beginning of each day's work. Rubber stamps for this purpose have been standardized and shall be used. Entries shall be made in every applicable space in each stamp. If, for special reason, additional information is believed desirable it should be entered just below the respective stamp or in the margin where it will not be overlooked; no important information should be omitted just because space has not been provided in one of the stamps.

If a change occurs during the day to affect any of the information, a new entry shall be made. If most of the information in one stamp is affected, use the stamp; otherwise make the entry in the "Remarks" column.

#### *8131. Personnel*

The names of the personnel engaged in the surveying, and the numbers of the instruments used by each, shall be entered in the appropriate spaces of Stamp No. 32, Personnel (fig. 175). Enter the last name in full, preceded by initials, unless the entry is a repetition, when initials will suffice. The correctness of the instruments used shall be verified and that fact noted after the number of each instrument. Figure 175 is a facsimile of Stamp No. 32 with the entries properly made.

| No. 32 | PERSONNEL | | |
|---|---|---|---|
| In charge | J. A. Smith | | Cor. |
| Plotter | J. A. S. | Protractor No. H 199 | OK |
| L. Angle | J. A. S. | Sextant No. H 209 | OK |
| R. Angle | A. A. Nelson | Sextant No. H 306 | OK |
| Recorder | P. L. Jones | Clock No. H 155 | OK |
| At chronograph | A. F. Sams | At fathometer | P. F. Apter |
| At sounding mach. | | Leadsman | C. M. Hoell |

FIGURE 175.—Facsimile of Personnel stamp with entries properly made.

When the operations are on a watch basis and most of the personnel are relieved at regular intervals, the stamp shall be repeated at the change of each watch. For temporary relief of members of the watch, or when only one person is relieved, appropriate notes in the "Remarks" column will suffice.

#### *8132. Sounding Apparatus*

The kind and instrument number of the sounding apparatus shall be entered in the appropriate spaces of rubber Stamp No. 33, Sounding Apparatus. Figure 176 shows this stamp with properly made entries. All of the apparatus which may be used during the day should be entered.

The calibration velocity of an echo-sounding instrument used shall always be entered, as well as the depths of the oscillator and hydrophone or transceiver, the setting

of the index, and the registration of the transmitted signal at the beginning of the day. Reference shall be made to the pages and volumes where bar checks (see **557**) and speed counts (see **555**) applicable to the day's work are recorded.

When a sounding machine is used, the sheave factor (see **4641**) and the date it was determined shall be entered.

No. 33 **SOUNDING APPARATUS**

Fathometer *Dorsey* Model *3* No. *36* Cal. Vel. *820* Fm/Sec.

Initial set *11 ft.* reading (shoalest edge) *10.9* ~~Fm.~~ Ft.

*Transceiver* ~~Osc.~~ No. *2* depth *12* Ft. Hyd. No........ depth........ Ft.

Bar check, pp.......... Vol.......... Speed count, pp........ Vol........

Sounding Mach. No. *95* Location *Stbd. Side For'd.* Sheave No. *H.83*

Sheave factor *1.0048* From test *April 22* 19*42*

Leadline No. *2* Graduated in *Feet*

Leadline comparison on page *43* Vol. *4*

FIGURE 176.—Facsimile of Sounding Apparatus stamp with entries properly made.

When a leadline is used, reference shall be made to all of the leadline comparisons (see **4622**) which are applicable to this day's work.

Any change during the day's work, which affects any of the information given in the stamp at the beginning of the day, shall be noted in the "Remarks" column.

### *8133. Preliminary Run and Weather*

The time the party or unit got underway or left headquarters and the distance in nautical miles to position 1 of the day's work shall be entered in Stamp No. 34 (fig. 177). The state of the weather, wind, and sea shall also be entered in this stamp.

| No. 34 | Depart | Arrive | Distance |
|---|---|---|---|
| Anchorage | *6:18* | | Mi. |
| Working grounds | | *7:26* | *13.2* Mi. |
| Underway at | | Weather *Overcast* | |
| Wind *SW 4* | | Sea *Moderate* | |

FIGURE 177.—Facsimile of Stamp No. 34 with entries properly made.

Any change which occurs during the day shall be noted in the "Remarks" column.

This same stamp shall be used at the end of the day's work to enter the distance from work and the time of arrival at headquarters.

### *8134. Comparison of Sounding Apparatus*

Any standardization or comparison of the sounding apparatus which is made at the beginning of the day's work or during the day shall be entered in columns below the headings of Stamp No. 35 (fig. 178).

The stamp is a multiple-purpose stamp to be used for leadline comparisons, fathometer comparisons, or bar checks. The two inapplicable headings should be crossed out each time the stamp is used.

The readings of the apparatus being tested should be entered in the left-hand column; the lengths or depths by the standard with which comparison is being made should be entered in the middle column; and the differences (first column entries subtracted from middle column entries) should be entered in the right-hand column. (See **4622** for verification of leadlines and **557** for bar checks.) When the leadline is tested and found to be correct for all depths for which it is to be or has been used, one entry stating this is sufficient, as in figure 178. (See also fig. 173.)

No. 35 ~~BAR CHECK~~

~~FATHOMETER COMPARISON~~

LEADLINE COMPARISON

| Mark or Fath. reading M | True length or depth D | Correction D-M |
|---|---|---|

*Leadline tested correct to 100 ft.*

FIGURE 178.—Facsimile of stamp for comparison of sounding apparatus with entries properly made.

## 814. COLUMN ENTRIES

As may be seen by reference to figures 172, 173, and 174, the pages of the Sounding Record are ruled into headed columns. It is important that each entry be made in the correct column and that the entries be neat enough so that they do not encroach on adjacent columns. Sloppy recording makes the subsequent interpretation of the records more difficult and may result in misinterpretation.

All of the events and data which are related to a specific time entry shall appear on the same horizontal line with the time, except for the position data where the first entry only falls on that line (see **8146**). Certain notations and miscellaneous entries in the "Remarks" column may be referred to their respective times by the use of appropriate corresponding reference marks at both.

Where it is necessary during the day's work to enter data or long explanatory notes which cannot be conveniently kept within the limits of the "Remarks" column, the record should be interrupted, the entire width of the double page used for the entry, and the record resumed below the entry.

### *8141. Position Numbers*

Positions shall be numbered consecutively starting with number 1 at the beginning of each day. These position numbers shall be entered, opposite their respective times, in the column headed "Position Number." Each number shall be within the angle symbol thus ($<$34); the symbol should be made with care so that it cannot be mistaken for part of the number or for the letter *I* or *L*.

Position numbers are to be given in accordance with **3312** and **6812**. When using R.A.R. control, each position in the Sounding Record on which there is a bomb shall be identified by the addition of a lower-case *b* to the position number. In the event that the bomb is a dud or that there are no usable results, the *b* shall be crossed out. Position numbers in the Bomb Record shall be identical with those in the Sounding Record (see **8311**).

No other entries shall appear in the "Position Number" column except the abbreviations *ah.* for ahead and *st.* for stop, which should be written close to the right-hand edge of the column.

465382—44——50

### *8142. Time*

Standard time shall be used in all hydrographic recording and the standard meridian shall be noted at the head of the "Time" column at the beginning of each day's work (see **151**). Time shall be recorded by numbering the hours consecutively from 0 (midnight) to 23 (11 p. m.).

All times shall be recorded in the "Time" column, with the corresponding data to which they refer entered on the same horizontal line. The exact time of each position, each recorded sounding, and each entry that will be used in plotting, must be recorded. Additional events which need to be timed in the Record are explained in different parts of this Manual—among the most important are: the time of an R.A.R. position (**6811**), the exact time of irregularly spaced soundings (**3431** and **3433**), the times of stopping for vertical casts and going ahead (**3422**), the times of changes in course (**3373**) and turns (**3463**), and the times of turns at ends of lines.

In connection with vertical casts, the abbreviations *st.* for stop and *ah.* for ahead shall be entered immediately preceding their respective times on the horizontal line, immediately before and after the respective soundings.

It is important that the exact times of the following detached events be recorded: detached soundings which are not a part of a sounding line; least depths on a shoal covered by drift sounding, or otherwise, with only the critical soundings recorded; positions to determine the outline or limits of an area where a tidal plane of reference is involved; a measurement or estimate of the height of a shoal or rock above the water, or an estimate of the depth of water over a feature on which a sounding cannot be taken.

If two or more clocks are used for the times of different parts of the recorded data, as in R.A.R. control, they must be set in agreement at the beginning of the day and verified at intervals throughout the day (see **6811**).

### *8143. Soundings*

The soundings shall be entered in the double column headed "Soundings", leaving one blank horizontal line after each position. Every sounding shall be recorded in fathoms and decimals, or feet and decimals (see **124**); no sounding shall be entered in fathoms and feet; fractions shall not be used. The integers of the numbers shall be recorded in the left-hand column, the tenths being recorded in the right-hand column. The depth unit shall be indicated by drawing lines through the inapplicable subheadings at the top of the double column on each page.

The depth units in which the soundings are to be recorded in various circumstances are specified in **3112**. There is no objection to changing from one unit to another in the recorded soundings; where this is done soundings shall be omitted from two horizontal lines, in which the new unit is to be boldly indicated (see fig. 172). Since only one depth unit is used on one hydrographic sheet (see **771** and **823**) it is more convenient that as large a percentage of the recorded soundings as practicable is in this unit, and that changes from one unit to another are held to a minimum.

Handlead soundings for comparisons, or interspersed with echo soundings, shall be in the same unit as the echo soundings.

*No bottom* soundings are almost valueless, but where they cannot be avoided they are to be recorded thus, $\frac{0}{18}$, meaning that at 18 (fathoms) bottom was not reached (see **3542**).

Soundings shall be recorded in integers, or to the nearest decimal part, according to table 29.

TABLE 29.—*Units for recorded soundings and corrections*

| Character of area or bottom | Depth range | For soundings in feet | | | | For soundings in fathoms | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | In protected waters | | In exposed waters | | In protected waters | | In exposed waters | |
| | | Record soundings to the nearest | Enter corrections to the nearest | Record soundings to the nearest | Enter corrections to the nearest | Record soundings to the nearest | Enter corrections to the nearest | Record soundings to the nearest | Enter corrections to the nearest |
| On dangers and shoals<br>On navigable bars<br>In dredged channels<br>At critical places in natural channels<br>In inside routes<br>For delineation of the low-water line | *fathoms*<br>0–10 | *foot*<br>0. 2 | *foot*<br>0. 2 | *foot*<br>0. 5 | *foot*<br>0. 2 | *fathom*<br>0. 1 | *fathom*<br>0. 1 | *fathom*<br>0. 1 | *fathom*<br>0. 1 |
| Over regular bottom<br>On the least depths in irregular bottom | 0–10 | 0. 5 | 0. 2 | 1. | 0. 5 | 0. 1 | 0. 1 | 0. 2 | 0. 1 |
| Elsewhere in irregular bottom | 0–10 | 1. | 0. 5 | 1. | 0. 5 | 0. 2 | 0. 1 | 0. 5 | 0. 2 |
| On shoals and banks<br>Elsewhere | over 10 | 1.<br>1. | 0. 5<br>1. | 1.<br>1. | 0. 5<br>1. | | | | |
| On shoals and banks and over regular bottom<br>Elsewhere | 11–31 | | | | | 0. 1<br>0. 2 | 0. 1<br>0. 1 | 0. 2<br>0. 5 | 0. 1<br>0. 2 |
| Over regular bottom<br>Elsewhere | 31–101 | | | | | 0. 2<br>0. 5 | 0. 1<br>0. 2 | 0. 5<br>0. 5 | 0. 2<br>0. 2 |
| Everywhere | over 101 | | | | | 1. | 0. 5 | 1. | 0. 5 |

### *8144. Bottom Characteristics*

The character of the bottom shall be entered in the column headed "Bottom", with the frequency specified in **3842**, using the standard abbreviations from part "S" of the Symbols and Abbreviations chart (fig. 189, part XI). Characteristics not on this chart shall be written out in full. The proper interpretation of many of the terms and miscellaneous instructions for recording them are given in **3845**, **3846**, and **3847**.

Detached determinations of the character of the bottom, as from the flukes of the anchor, from a buoy anchor, or at a serial temperature station, must always be accompanied by a position—by the best estimated position from dead reckoning if a fixed position cannot be obtained (see **3841**).

### *8145. Compass Heading*

The vessel's heading by compass at all times during sounding shall be entered in the column headed "Heading by ------------------ Compass"; and in the blank space shall be indicated whether the *steering* or *standard* magnetic compass or gyrocompass of major survey units is in use.

In launch and small-boat hydrography controlled by three-point fixes, and in hydrography controlled by ranges or distance angles, compass headings may be omitted. If they are omitted, the general direction of the line being run (unless distance angles are used) shall be entered in the "Remarks" column. If ranges or distance angles are being used that fact shall be entered vertically in the compass heading column. With the above exception, no entries except headings shall be made in this column. Entries, such as *c/c* and *o/c* to indicate "changed course" and "on course" properly belong in the "Remarks" column.

All courses shall be entered in degrees, clockwise from north.

Course entries in connection with changes in course and turns shall be in accordance with **3454** and **3463**. A time entry should be made in the "Time" column opposite each course entry.

### *8146. Position Data*

Insofar as practicable, all position data, except R.A.R. distances, shall be entered in the column provided in the center of the right-hand page. It is disconcerting to have a part of these data recorded in the "Remarks" column.

The first entry of position data shall invariably be on the same horizontal line with the corresponding time and position number on the left-hand page, followed on consecutive lines by the remainder of the position data. The position number and symbol which appear on the left-hand page shall be repeated immediately to the left of the top entry of position data (see **8141**).

The required frequency of position is specified in **3313** and **6812**.

*Three-point fix.*—The names of the three stations of a three-point fix shall be recorded vertically in the left part of the column, with the name of the center station indented slightly. The objects shall always be recorded clockwise, that is, the left object first, the center object next, and the right object last. The angles are recorded in the right part of the column, the left and right angles being recorded opposite the names of the left and right stations respectively.

A three-point fix shall always be recorded between two heavy ruled horizontal lines, leaving as many blank spaces in the "Time" and "Soundings" columns as are necessary to accomplish this.

Where the same control stations are used for successive fixes, it is not necessary to repeat the names; the word "same" or the letter S, covering the three spaces occupied by the fix, may be used at each position to indicate a repetition, provided that the station names are entered for the first position on each page and every time any one of the stations is changed.

Supplemental angles, or cuts, observed at three-point fixes are recorded below the corresponding fixes, preferably with one blank intervening space. The names of the two objects, recorded clockwise, are entered on the same line with the "cut" angle.

The recorded names of stations must agree with those on the boat sheet (see **3245**).

In addition to the systematically spaced positions, supplemental positions and supplemental angles are often required as explained in different parts of this Manual. Some of the most important of these are specified in **3312** and **3313**. Others occur in connection with locating buoys (see section **25**) and hydrographic stations (**243**, **247**, and **248**). Others occasionally required are: in connection with revision of the high-water line (**3244** and **381**); to locate a vessel for use as a hydrographic station (**3365**); on a navigational range to determine its azimuth (**3833**); in connection with drawing form lines from the vessel (**382**); to locate rocks, obstructions, wrecks, etc., (see **363**, **364**, and **365**).

If one of the objects of a three-point fix is a distant tangent, the height of eye must be included (**3336*b***). If one of the objects is appreciably above the horizon, its vertical angle must be included (**3338**).

*R.A.R. position.*—R.A.R. distances are recorded in the Bomb Record and shall not be repeated in the Sounding Record. The position numbers and symbols shall be entered in the Sounding Record, and opposite the first number on each page the entry "See Bomb Record" shall be made. Extreme care must be taken to ensure that the times and numbers of the corresponding positions in the two Records agree (see **6811** and **8311**).

All additional position data, such as log readings, engine revolutions, and bearings, are recorded in the Sounding Record (see **6811**). Rubber Stamp No. 24 (fig. 179) shall be used for this purpose so far as applicable.

No. 24
Position No. ...44.......
Log.......56.50.......
R. C.....787603.....

FIGURE 179.—Facsimile of stamp for log and revolution-counter readings

Supplemental positions, for which there are no R.A.R. distances, are often required in connection with R.A.R. (see **3312**, **3313**, and **6812**). Each of these shall be given a consecutive number. Since these are not entered in the Bomb Record, the result is that the position numbers in the Bomb Record are not consecutive.

*Miscellaneous control data.*—A numbered position shall be given to each entry of control data which will be used in plotting the sounding line, regardless of its nature, including the times at some changes in course (see **3373**).

*Bearings.*—Where recorded for use as position data, the number of degrees shall be followed by **T** to indicate a true bearing, and by *p.s.c.* to indicate a compass bearing. In the latter case the values of the variation and deviation shall be entered and the bearing converted to a true bearing during or at the end of the day's work.

*Ranges.*—Where sounding lines are run on pre-established ranges the positions may be numbered and the data recorded in accordance with **334**.

## 815. REMARKS AND MISCELLANEOUS ENTRIES

In the "Remarks" column shall be entered all additional information required for the proper understanding and correct plotting of the work, for which provision

has not been made in other columns. Abbreviations (**8111**) can be used for many routine entries.

Among the entries which recur frequently are the following:

(*a*) The latitude and longitude shall be entered at the first position of each day's work, at the beginning of a system of contiguous lines, at each detached sounding in a new locality, and at the beginning of a line in a locality different from the last previous recorded position. Use rubber Stamp No. 39, Line Begins (fig. 180).

(*b*) The words "line begins" and "line ends," or their abbreviations, are to be used at the beginning and end of adjacent lines, in accordance with **3454**, where soundings around the turns are not recorded or are not intended to be used on the smooth sheet. The words "line turns" should be entered in the "Remarks" column only when a turn is made in a continuous line of soundings.

| No. 39 | LINE BEGINS |
|---|---|
| Lat *43°-39.6′* | Long *70°-07.8′* |

FIGURE 180.—Facsimile of Line Begins stamp.

(*c*) The abbreviation "L. T. L." or "L. T. R." shall be entered after the entry "line ends" to indicate the direction the vessel turns to proceed to an adjacent line.

(*d*) Changes affecting any of the information given at the beginning of the day's work (see **813**).

(*e*) Notation of a change in locality of work or a change of sheet, including the ship's run (in nautical miles).

(*f*) Distance (in meters) and direction of features in the water area, such as aids to navigation, rocks, breakers, and shoals, where passed close by. Indicate if the distance is estimated (do not scale distances from sheet for this purpose). If depression angles are recorded, record the height of eye also. (See **3353**.) Indicate whether the object has been previously located or whether the data entered are to be used to locate it. (See also **363**.)

(*g*) Estimated distances (in meters) to the high-water line, to the low-water line, to reef lines, to kelp, etc., from the nearest recorded position (see **3122** and **754**). Explanatory notes in regard to any areas not completely surveyed.

(*h*) Complete notes relative to methods used in revising the high-water line or topography and any data which do not properly belong in other columns. (See **3244**, **381**, and **753**.)

(*i*) Notation of all changes in speed (**3461**). Note any sounding lines started from a standstill (**3451**).

(*j*) Measurements or estimates of heights of exposed rocks, if not previously well determined (**3244** and **363**), and estimated depths over rocks, shoals, and areas, which cannot be sounded over (**364**). Such elevations and depths shall be referred to the water level, and the time of observation shall be entered in the "Time" column; they should never refer to a plane of reference.

(*k*) The time spent in examining a shoal by drift soundings, or otherwise, where systematic lines are not run (**3312**(*e*) and **3666**).

(*l*) Complete and comprehensive notes regarding the examination of shoals shall be given, including the method of search used; a statement as to whether or not bottom was visible; apparent size of the top and base of shoal; kind of bottom; presence or absence of kelp or grass; least depth found; and such additional information to enable the reviewer to determine whether or not the examination was adequate. (See **3312**(*e*) and **3666**.)

(*m*) The reason for the correction or rejection of any recorded data. Any entry which appears unlikely by reference to other recorded data shall be verified immediately, the entry checkmarked (√) and notation made in the "Remarks" column that it was verified immediately after having been recorded.

(*n*) Notation of any visual echo-sounding instrument which is not operated or attended continuously (**3415**).

(*o*) Mention of any current encountered.

(*p*) The reason for *missed* soundings (**3542**).

(*q*) A record of any marine growth encountered, its length, thickness, and whether it is visible on the surface of the water. Note the value as an indication of danger of any kelp encountered (**7864**).

(*r*) Wrecks, wreckage, and obstructions should be described (**365**).

(*s*) Explanation of any time not spent in sounding.

(*t*) Notation of a change from one method of sounding to another.

(*u*) Any condition of sea or weather which affects materially the accuracy otherwise expected in the recorded data.

(*v*) Notation of any echo soundings taken when the vessel is stopped or proceeding at slow speed, with an instrument that has been adjusted to compensate for settlement and squat (**57**(*j*)).

Descriptive Report notes (**385**) do not take the place of notes properly belonging in the Sounding Record.

Stations or objects cut in should be described at the time the first cut is recorded (**248**). Notations should indicate where the track between fixes should be taken from the boat sheet (**3352**). Where positions outlining an area are recorded, a description of the area shall be made, differentiating particularly between a reef and a sandy low-water line (**7824**). Sketches should be included of the more important reefs.

A multitude of various miscellaneous entries are required, too numerous to be discussed individually.

Where notes are too long to be entered in the "Remarks" column, the sequence of recording may be interrupted to record a note the entire width of the page.

## 816. Information at End of Day's Work

At the end of each day's work certain entries are required. Rubber stamps are provided for most of these and entries shall be made in every applicable space in each stamp. See also the instructions in **813**.

The registration, at the end of the day, of the transmitted signal of any echo-sounding instrument used shall be entered in the "Remarks" column.

A leadline comparison and a bar check are required at the end of the day, using rubber Stamp No. 35 in accordance with **8134**.

The time of arrival at and distance to headquarters are required, using rubber Stamp No. 34 (see **8133**).

A verification of the sextants and clock used is required at the end of the day, using rubber Stamp No. 36 (fig. 181). This stamp also includes spaces for the signatures of the officer-in-charge and the Chief of Party (see **818**).

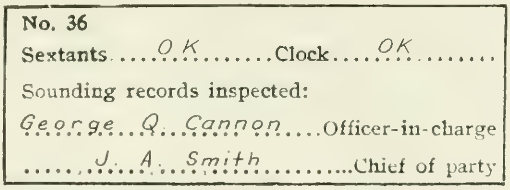

No. 36
Sextants ....O K........Clock....OK........
Sounding records inspected:
George Q. Cannon....Officer-in-charge
......J. A. Smith..........Chief of party

Figure 181.—Facsimile of stamp for verification of sextants and clock.

In connection with the reduction of the records, rubber Stamp No. 38, Processing (fig. 183), is required (see **824**). Unless this stamp is impressed as each day's work is completed, space must be left for it. The location of the tide gage used during the day shall be entered in this stamp in the space provided.

### *8161. Statistics*

The statistics for each day's work shall be given at the end of each day, using rubber Stamp No. 37, Statistics (fig. 182). Where a day's work is recorded in two volumes, the statistics shall be divided between the two volumes, the stamp being used at the end of the record in the first volume, as well as at the end of the day in the second volume. The stamp provides columns for this division. (See also **124**.)

Echo soundings are not to be counted—note that the stamp specifically indicates that only handlead and wire soundings are to be counted.

No. 37 STATISTICS...G...DAY

| | This Vol. : | Total | |
|---|---|---|---|
| No. sdgs. (H. L. and wire) | ....16.....: | ...16.... | |
| No. positions | ....73.....: | ...78.... | |
| Miles sdg. line....:..106.3....Naut | ....114.3 ...: | ..122.4..... | Stat. |
| Dist. to and from:...29.4...Naut. Mi. | | | |
| Misc. dist. run....:.....6.2...Naut. Mi. | : | ....141.9.... | Naut. |
| Sounding continued in volume.................................... | | | |

FIGURE 182.—Facsimile of Statistics stamp with entries properly made.

## 817. Other Sounding Records

Two experimental forms of Sounding Records have been devised, whose use is under consideration for echo soundings recorded graphically. Although the arrangement is radically different from Form 275, many of the column headings are the same, and the same instructions should be followed in using them.

The principal innovations in the new forms are that two are used, the soundings being recorded separately from the position data and other data, and that data are recorded horizontally instead of vertically. The data in the separate volumes are correlated by time and position numbers.

In the form in which the position data are recorded, the names of the stations and angles of a three-point fix are recorded on one horizontal line—left object, left angle, center object, right angle, and right object. Cuts are recorded in a similar manner. One blank horizontal line is left between positions. The bottom characteristics are recorded in the "Remarks" column.

The form in which the soundings are recorded is intended for the temporary use of the hydrographer in inking the soundings on the boat sheet. It is *not* to be used as an official record of soundings, the fathogram itself serving for this purpose and the soundings being plotted and inked on the smooth sheet from the fathogram. (See **562**.)

In the new form the soundings are recorded on a horizontal line, which is divided into 10 numbered columns. Soundings are recorded on the assumption that all are equally spaced. The position number and the time of the position are recorded. The times of intermediate soundings are omitted. The sounding on the position is entered in the first column, which may be considered the *zero* column, and the successive columns are numbered from 1 to 9. For example, if five equally spaced soundings are taken between two successive positions, they are entered on a horizontal line in columns numbered 1 to 5, a line being drawn through the remaining spaces. If more than nine soundings occur between positions they can be entered on a second line, the tenth sounding after the position being entered in the first column, numbered 10.

If an occasional shoal or deep sounding needs to be interpolated between two soundings at regular intervals, it can be inserted above the line with a caret below to indicate this. The form is of no value where many soundings have to be recorded at irregular intervals.

One blank horizontal line should be left between entries. If a reduction for tide is necessary for boat-sheet soundings, it may generally be made mentally as the soundings are inked on the boat sheet. If it is necessary to reduce the soundings arithmetically for tide before they are inked on the boat sheet, enough blank horizontal spaces should be left in the record for this reduction, the reduced soundings being entered vertically below the corresponding soundings before reduction.

### 818. Supervision and Inspection

Although the officer-in-charge is responsible for the records, he is usually fully engaged otherwise during the actual sounding, and his assistant, usually the right angleman, shall supervise the actual recording and check closely the marner and accuracy with which the recorder does his work. It is the latter who usually tells the recorder what miscellaneous entries to make. He should see that clear explanatory notes are entered wherever necessary. Some hydrographic or topographic information is found only in the "Remarks" column. Such notes are often of supreme importance, as for example, those referring to rocks awash and revision of shoreline. He should make certain that they are adequate and accurate. Question marks should not be left in the Record to cause future confusion. Rejections of shoal soundings, which may be obvious to the hydrographer, should be logically and fully explained. (See **3413**.)

A daily review of the boat sheet and Sounding Record shall be made by the hydrographer at which time any errors or omissions in the recorded data should be rectified (see **3246**).

The hydrographer in charge of the party, or of the watch if on board ship, shall be responsible for the accuracy and adequacy of the recorded data and at the end of the day's work or watch shall approve the record for that day, or watch, over his signature (see **3412**). The signature shall be entered in the appropriate space in Stamp No. 36 (fig. 181) which should be impressed at the end of each day, or each watch if operations are on a watch basis.

Sounding Records shall be examined occasionally by the Chief of Party to make sure that they are being kept in accordance with the requirements and are complete and satisfactory in all respects. The examination required is only a general one, the hydrographer in immediate charge being specifically responsible for the day-to-day examination and for the approval of each day's recorded data. The Chief of Party need not sign the Sounding Records. The space provided in Stamp No. 36 may be disregarded. If the Chief of Party does inspect the Records generally, he may place his signature in this space, with inclusive dates to indicate that part of the Records to which his inspection applies.

General instructions to the hydrographer by the Chief of Party should be written in the Sounding Record and signed by him. (See also **3411**.)

### 819. Completion of Sounding Records

After the completion of a hydrographic survey, all of the Sounding Records for that survey shall be gathered together and the following completion steps accomplished:

*a. Numbering.*—The Records are to be grouped in the proper order, the various groups shall be combined, and the complete set of Records shall be numbered consecutively and permanently, including any volumes used solely for cuts or other miscellaneous data.

The field number and registry number of the hydrographic survey shall be plainly marked *in pencil* on the cover label and the title page of each volume of soundings. In the relatively rare case where parts of a Sounding Record have to be plotted on different smooth sheets, the numbers of both surveys shall be entered on the cover label and reference must be made on the proper pages of the Record to the sheets involved. It is not necessary to copy a portion of the Record into another volume. (See **3213**.)

*b. Cover label.*—The data called for on the cover label and title page shall be entered in black drawing ink, except the position numbers and day letters, which shall be entered with ink of the color or colors used in the Record, and the survey numbers which are left in pencil.

*c. Deviation table.*—The deviation table for the compass used for hydrography shall be entered on page 1 of the first volume of each set of Records, and in the proper Record (with reference to date) if

changed during the course of the survey. This is not necessary for launches and small boats using portable compasses. (See **144**.)

*d. Index of cuts.*—An index of all objects such as signals, survey buoys, aids to navigation, landmarks for charts, rocks, and breakers, the positions of which have been determined by sextant angles, shall be entered as follows: If a separate volume contains all such data, the index shall be entered on page 2 of that volume; if the data are interspersed through the Sounding Records, the index shall be entered on page 2 of volume No. 1, giving the volume and page numbers on which are recorded all data for the location of any given station or object (see **248**).

References to positions taken to determine the azimuths of ranges shall be included in this index (see **7845**).

*e. Index of hydrographic information.*—A separate index of special hydrographic information such as currents, tide rips, overfalls, and swirls shall be entered on page 2 of volume No. 1. Any detached determinations of the character of the bottom not recorded in the Sounding Records shall also be indexed.

*f. List of stations.*—An alphabetical list of the stations used on each hydrographic sheet shall be prepared, in accordance with **2154**. If typed, this should be pasted inside the title page of sounding volume No. 1 for that sheet or, if desired, it may be lettered on the first record pages, from which hydrography has been omitted for this purpose.

Where a station has been relocated by a more accurate method, after having been used on the boat sheet, this fact shall be noted in the list (see **241**).

*g. Buoy positions.*—Where buoys have been located by sextant cuts recorded here and there throughout the Sounding Records, the cuts are to be indexed in accordance with *d* "Index of cuts." Where final buoy positions based on these cuts have been determined by the field party by computation, by plotting on an aluminum sheet, or otherwise, that fact must be made clear in the index. Those cuts that are to be plotted on the smooth sheet to determine buoy positions shall be properly identified.

All buoy stations whose final positions have been determined by the field party, by any method other than by plotting on the smooth sheet, must be included in the list of buoy stations required in the Descriptive Report (see **8435**).

## 82. REDUCTION OF SOUNDINGS

Recorded soundings must be corrected for any departure from true depth due to the method of sounding or to a fault in the measuring apparatus and for the height of the tide above or below the plane of reference at the time of sounding. Vertical columns are provided in Form 275, Soundings, in which to enter the corrections and the soundings after reduction.

### 821. Correction Units

Corrections (sometimes called reducers) shall be entered in the same unit in which the soundings have been recorded (see **3112** and **8143**). Parts of units shall be entered in decimals—fractions shall not be used. Where the soundings have been recorded in feet, the corrections shall be entered in feet and tenths; where the soundings have been recorded in fathoms, the corrections shall be entered in fathoms and decimals. Lines shall be drawn through the inapplicable unit at the top of each column on each page.

### 822. Corrections to Recorded Depths

Each correction, preceded by the proper arithmetic sign, shall be entered on the horizontal line opposite the first sounding to which it is applicable and need not be repeated, except opposite the first sounding on each page and at the beginning of each sounding line. A correction or sign once entered shall be considered applicable to all following soundings until a different correction or sign is entered.

In depths over 100 fathoms, all corrections may be omitted where the algebraic sum of the maximum tide correction for the day's work and all other corrections is less than one-half percent of the depth. Thus in reducing echo soundings, if the velocity correction for 350 fathoms is −0.7 fathom and the maximum tide reducer for the day is −0.7 fathom, the corrections may be omitted for that depth because the sum of the corrections is only 0.4 percent of the depth. On the contrary, if the maximum tide reducer were −1.1 fathoms, the total correction would be slightly greater than 0.5 percent of the depth and corrections could not be omitted, even though at the actual time of sounding the tide reducer may have been such as to bring the total correction below 0.5 percent. Corrections must not be omitted when the tide is low and entered when it is high.

Corrections shall be entered according to table 29 (see **8143**). It should be noted that, in general, the corrections are to be entered to a decimal which is one-half that required in recording the soundings, using 0.2 where the requirement for recording is 0.5. Exceptions are: that no entry in feet need be closer than 0.2 foot and no entry in fathoms need be closer than 0.1 fathom; and for soundings over 60 feet, except on shoals and banks, corrections need be entered only to the nearest foot. Used in conjunction with table 29, the following tabulation may be helpful:

| Where soundings are recorded to the nearest | Enter corrections to the nearest |
|---|---|
| *foot* | *foot* |
| 0. 2 | 0. 2 |
| 0. 5 | 0. 2 |
| 1. 0 | 0. 5 } *see text* |
| 1. 0 | 1. 0 } *see text* |
| *fathom* | *fathom* |
| 0. 1 | 0. 1 |
| 0. 2 | 0. 1 |
| 0. 5 | 0. 2 |
| 1. 0 | 0. 5 |

The range through which any correction is to be applied is as follows:

Where corrections are entered to the nearest 0.5 foot or less, and to the nearest 0.1 fathom, the range covered shall be from one-half below to one-half above the correction applied, according to the following tabulation:

Whether *added* to or *subtracted* from the sounding

*Range*

0. 1 to 0. 3 foot = 0. 2 foot
0. 3 to 0. 5 foot = 0. 4 foot
0. 5 to 0. 7 foot = 0. 6 foot
etc.

0. 25 to 0. 75 foot = 0. 5 foot
0. 75 to 1. 25 feet = 1. 0 foot
1. 25 to 1. 75 feet = 1. 5 feet
etc.

0. 05 to 0. 15 fathom = 0. 1 fathom
0. 15 to 0. 25 fathom = 0. 2 fathom
0. 25 to 0. 35 fathom = 0. 3 fathom
etc.

Where corrections are entered to the nearest 1.0 foot or to the nearest 0.2 fathom or greater, the range covered shall be eccentric, from one-fourth below to three-fourths above the correction applied, or vice versa, according to the following tabulation:

*Range*

| *Corrections added* | *Corrections subtracted* |
|---|---|
| −0. 25 to +0. 75 foot= 0 foot | −0. 25 to −1. 25 feet=−1. 0 foot |
| 0. 75 to 1. 75 feet=1. 0 foot | −1. 25 to −2. 25 feet=−2. 0 feet |
| 1. 75 to 2. 75 feet=2. 0 feet | etc. |
| etc | |
| −0. 05 to +0. 15 fathom= 0 fathom | −0. 05 to −0. 25 fathom=−0. 2 fathom |
| 0. 15 to 0. 35 fathom=0. 2 fathom | −0. 25 to −0. 45 fathom=−0. 4 fathom |
| 0. 35 to 0. 55 fathom=0. 4 fathom | etc. |
| etc. | |
| −0. 125 to +0. 375 fathom = 0 fathom | −0. 125 to −0. 625 fathom =−0. 5 fathom |
| 0. 375 to 0. 875 fathom =0. 5 fathom | −0. 625 to −1. 125 fathoms=−1. 0 fathom |
| 0. 875 to 1. 375 fathoms=1. 0 fathom | etc. |
| etc. | |

### *8221. Leadline Corrections*

Leadline corrections shall be entered in the "Correction" column headed "Leadline." They result from the use of a leadline of incorrect length, whose comparison with a standard has given the corrections to be applied (see **4622**). The corrections to be entered are derived from the entries made in Stamp No. 35 (fig. 178), at the beginning and end of the day, and sometimes during the day.

If the length of a leadline changes appreciably between comparisons, the corrections shall be proportioned according to the length of time it was used for sounding.

### *8222. Wire Sounding Corrections*

Wire sounding corrections are also entered in the "Correction" column headed "Leadline." They result from the use of a worn registering sheave, or from the use of stranded wire (see **4641**). The sheave factor is entered at the beginning of the day in Stamp No. 33 (fig. 176). The corrections to be entered are found by multiplying the recorded soundings by the sheave factor.

### *8223. Echo-Sounding Corrections*

Velocity corrections to echo soundings shall be entered in the "Correction" column headed "Echo." They result from the actual mean velocity of sound from surface to bottom differing from the calibration velocity of the particular echo-sounding instrument (see section **56**). There are two general methods by which the corrections are derived, an indirect and a direct one.

In the indirect method the corrections are obtained by numerical or graphic means from observed temperatures and salinities (see **5613** and **5615**). In the direct method, also known as the *bar check* method and used for soundings in shoal depths, corrections are obtained by direct comparison (see **5617**). In both methods the data are used to plot a correction curve, from which is tabulated the range through which each correction applies (see **5614**).

In either case the corrections applicable to the various depths are entered in the Sounding Record from a table, a copy of which is included in the Descriptive Report (see **8434**).

Echo-sounding instruments are intended to be adjusted and operated so that the velocity and tide corrections are the only corrections that need be applied to echo soundings (see **55** and **56**). If for any reason, an additional correction is found to be necessary, it should be entered separately in the "Correction" column headed "Slope" and appropriately headed.

The effect of an erroneous motor speed on the calibration velocity should be noted (see **5553**). This should be taken into account by basing the velocity corrections on the actual instrumental velocity instead of on the standard calibration velocity (see table 20).

*8224. Tide Reducers*

The recorded soundings must be corrected for the height of the tide above or below the plane of reference at the times of the soundings. These corrections are entered in the "Correction" column headed "Red. for Tide."

The planes of reference adopted for the reduction of soundings and the publication of charts of the Coast and Geodetic Survey are as follows (see also **2172**):

(*a*) For the Atlantic Ocean and Gulf of Mexico—the mean of the low waters (MLW).

(*b*) For the Pacific Ocean—the mean of the lower low waters (MLLW)—except for the Pacific entrance to the Panama Canal where it is the mean of the low water springs (MLWS).

(*c*) For certain of the larger navigable rivers and lakes special planes have been adopted.

The location of the tide gage to be used in connection with each day's work shall be entered in the appropriate space in Stamp No. 38, Processing (fig. 183), at the end of the day (see also **4672**).

The tide reducers are derived from marigrams from automatic tide gages, generally established especially for this purpose, or occasionally from observed tides (heights read from a staff).

After the height of the plane of reference for the particular gage or staff has been received from the Washington Office (see **1215**) the reducers can be scaled directly from the marigrams, if available, and entered in the Records.

In most cases the marigrams or records of staff readings must be sent to the Washington Office before the plane of reference is determined. In such cases copies must be made of those parts of the marigrams needed, or the hourly heights must be scaled, from which curves can be reconstructed. The reducers can then be scaled from the copies or the reconstructed curves when needed.

Full instructions for deriving the reducers are contained in Special Publication No. 196, Manual of Tide Observations.

## 823. Units of Final Reduced Soundings

The algebraic sum of all corrections applicable is added to or subtracted from each sounding, the result being entered in the double column headed "Field" under "Reduced Soundings." These reduced soundings will be in the same depth units as the recorded soundings. The unit shall be indicated by drawing lines through the inapplicable subheadings at the top of the double column on each page. (See fig. 172.)

This may result in some reduced soundings being in fathoms and tenths and some in feet and tenths on the same hydrographic survey, or even on the same page of the Record. In the latter case the change of unit must be boldly indicated, at the place in the column where it occurs.

Only one depth unit is used on one hydrographic sheet (see **771**). For convenience in plotting, all soundings shall finally be converted to the one depth unit to be used

on the particular survey sheet. Those reduced soundings that are in the unit which is not to be used, shall be converted to the appropriate unit in accordance with the conversion tables in **7716**, the results being entered in the double column headed "Office." The unit must be indicated by drawing lines through the inapplicable subheadings at the top of the double column.

The result will be that the right-hand entries on the left page of the Sounding Record will be in the same depth unit—that to be used in plotting the smooth sheet.

### 824. Verification of Reduced Soundings

The entries of the various corrections (**822**) and the reduction of the soundings and the final reduced soundings shall be checked. To indicate that this has been done, a checkmark shall be placed opposite each correction entry and at the bottom of each column of reduced soundings. If there are numerous correction entries in a column, one checkmark at the bottom of the column will suffice. Rubber Stamp No. 38, Processing (fig. 183), shall be impressed at the end of each day's record, and the initials of the persons who made the original entries and of those who checked them shall be entered in the appropriate spaces.

| No. 38 | PROCESSING |
|---|---|
| STANDARD Tide Gage at | PORTLAND ME. |
| Plane of Ref. M. L. W. | Entered:Checked |
| Tide Red. | J. A. S.: A. A. N. |
| Leadline Cor. | J. A. S.: A. A. N. |
| Index Cor. | R. A. G.: G. C. W. |
| Vel. Cor. | R. A. G.: G. C. W. |
| Soundings reduced | J. A. S. A. A. N. |
| Positions plotted | H. J. B. |
| Graph scaled | J. C. E. |
| Soundings penciled | H. J. B. |

FIGURE 183.—Facsimile of Processing stamp with entries properly made.

### 825. Errors Detected During Plotting

In spite of the fact that all correction entries and all reduced soundings are checked in the field, serious mathematical errors have been found during the smooth plotting. The entry of the tide reducers is the only step in the reduction of the Sounding Record which is checked at the Washington Office. This is done because the plane of reference may be known more accurately after the receipt of the Sounding Records, but not to provide an additional check.

Mathematical errors found during the smooth plotting shall be corrected, but no other deviation from the Record shall be made unless it is reasonable and supported conclusively by other evidence. All corrections made on the left-hand page of the Record by the smooth-sheet plotter shall be made with colored pencil and be fully explained or justified by a note in the "Remarks" column. The Record and the smooth sheet, when completed, must be in full agreement. (See also **774**.)

## 83. MISCELLANEOUS RECORDS

When a hydrographic survey was relatively simple, as before the advent of echo sounding and Radio Acoustic Ranging (R.A.R.), the Sounding Record usually sufficed for the entry of all the hydrographic data. Due to the complexity of modern hydrographic surveys—particularly offshore ship surveys—there are essential data which cannot conveniently be included in the Sounding Record, but which form a part of the permanent records. It is with these miscellaneous records that this section deals.

These records should be just as clear, complete, and self-explanatory as the Sounding Records and the same precautions are required in the recording (see **81**).

### 831. Position Records

When it can be done conveniently it is always desirable to keep the complete record of a hydrographic survey in one book—the Sounding Record. Using certain types of control, however, it is necessary to record the position data in a separate record, and it may occasionally be more convenient to do so even when using three-point fix control. The sextant observers may have to station themselves on the flying bridge, or elsewhere, at some distance from the echo-sounding instrument, where it is inconvenient and conducive to error, to record both the position data and soundings in the same record book. There is no objection to separate records in such cases but the greatest care must be taken to correlate the two records accurately by time and position numbers.

In surveys controlled by R.A.R., the position data are received at the chronograph station, usually in the radio room and frequently some distance from the ship's bridge or the plotting room, and a separate Bomb Record must be used for the data.

Position data for dead reckoning, and often in connection with R.A.R. surveys, are abstracted on a special form designed for this purpose.

Astronomic sights also are recorded and computed separately.

#### *8311. Bomb Record*

In surveys controlled by Radio Acoustic Ranging (R.A.R.), described in chapter 6, the Bomb Record (Form 670) is the official record of the R.A.R. position data. For plotting positions based solely on R.A.R. distances, the data shall be complete in the Bomb Record, and reference to other records should not be necessary. But the dead reckoning and all supplemental data, such as bearings and sextant angles, shall be recorded in the Sounding Record. R.A.R. position data shall not be repeated in, nor copied into, the Sounding Record.

R.A.R. distances measured to locate buoy stations (see **2533**, **2534**, **2573**, and **2574**) shall also be recorded in the Bomb Record. This Record shall be the original source of the data used to determine buoy positions by this method (see **8324**). R.A.R distances measured to determine the velocity of sound experimentally shall also be recorded in the Bomb Record, but the corresponding observations or measurements to determine the horizontal distances are either recorded in the Sounding Record or on special forms designed for taut-wire measurements (see **8323**).

Entries in the Bomb Record are made at the chronograph station, usually by the chronograph attendant (see **6712**). The entries must be clear and complete and the general instructions for recording in the Sounding Record must be followed (see **81** and **811**).

The Bomb Record and the Sounding Record are identical in shape and size and are very similar in outward appearance. A sample double page of the Bomb Record is shown in figure 184, in which the approved manner of recording R.A.R. data is illustrated. The Record is designed for the use of shore stations and it is arranged so that the returns from two stations may be recorded in the space to which one position number is assigned. But R.A.R. control is now planned with a view to getting at least three bomb distances at a position, so each double page of the Record shall be used as a continuous horizontal record, the data for one position being carried across both pages,

Form 670 — 57

**BOMB RECORD** — *Locality* S. OF NANTUCKET SHOALS

*Year 19* *Month* SEPT 15 1941 *Day of Month* — *U. S. C. and G. Survey Ship* LYDONIA ; *GA day*

| BOMB NO. 89 | ¼ PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: 14 H. 18 M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: Esau | | 8 16 | 8 56 | 8.75 | |
| 10 KNOTS | INITIAL INTERVAL | + 32 | | $\gamma_1$= 1493 | $V_1$= |
| 11 SEC. RUN; CORR'N | | + 08 | | $\gamma_2$= 1490 | $V_2$= |
| STATION$_2$: DAGO | | 18 95 | 19 35 | 19.75 | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$: O.K.
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

| BOMB NO. 89 | PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: H. M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: GOBY | | 27 57 | 27 97 | 28.66 | |
| KNOTS | INITIAL INTERVAL | + 40 | | $\gamma_1$= 1496 | $V_1$— |
| SEC. RUN; CORR'N | | + | | $\gamma_2$= | $V_2$= |
| STATION$_2$: | | | | | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K , STATION$_2$:
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

| BOMB NO. 90 | ¼ PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: 14 H. 28 M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: E | | | N R | | |
| 10 KNOTS | INITIAL INTERVAL | + 96 | | $\gamma_1$= — | $V_1$= |
| 10 SEC. RUN; CORR'N | | + 08 | | $\gamma_2$= 1491 | $V_2$= |
| STATION$_2$: D. | | 21 13 | 22 17 | 22.64 | |

CLEARNESS OF TAPE RECORD, STATION$_1$: Static , STATION$_2$: O.K.
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: Clock time checked with bridge 11—9490

| BOMB NO. 90 | PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: H. M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: G. | | 25 23 | 26 27 | 26.92 | |
| KNOTS | INITIAL INTERVAL | + 104 | | $\gamma_1$ 1496 | $V_1$— |
| SEC. RUN; CORR'N | | + | | $\gamma_2$ | $V_2$= |
| STATION$_2$: | | | | | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$:
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

| BOMB NO. 93 | ½ PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: 14 H. 36 M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: E. | | 10 86 | 11 32 | 11.58 | |
| 10 KNOTS | INITIAL INTERVAL | + 37 | | $\gamma_1$= 1493 | $V_1$= |
| 12 SEC. RUN; CORR'N | | + 09 | | $\gamma_2$= 1491 | $V_2$= |
| STATION$_2$: D. | | 23 56 | 24 02 | 24.53 | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$: O.K.
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

| BOMB NO. 93 | PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: H. M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: G. | | Obscured by return from DAGO | | | |
| KNOTS | INITIAL INTERVAL | + 46 | | $\gamma_1$= — | $V_1$= |
| SEC. RUN; CORR'N | | + | | $\gamma_2$= | $V_2$= |
| STATION$_2$: | | | | | |

CLEARNESS OF TAPE RECORD, STATION$_1$: N. R. , STATION$_2$:
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

| BOMB NO. 95 | ½ PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: 14 H. 46 M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: E. | | 12 31 | 12 93 | 13.21 | |
| 10 KNOTS | INITIAL INTERVAL | + 53 | | $\gamma_1$= 1492 | $V_1$ |
| 12 SEC. RUN; CORR'N | | + 09 | | $\gamma_2$= 1497 | $V_2$= |
| STATION$_2$: GOBY | | 23 05 | 23 67 | 24.27 | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$: O.K.
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: Line ends to bomb @ Buoy Keen 11—9490

| BOMB NO. 95 | PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: H. M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: DAGO | | 25 00 | 25 62 | 26.16 | |
| KNOTS | INITIAL INTERVAL | + 62 | | $\gamma_1$= 1491 | $V_1$= |
| SEC. RUN; CORR'N | | + | | $\gamma_2$ | $V_2$— |
| STATION$_2$: | | | | | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$:
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

Bombing @ Buoy KEEN

| BOMB NO. 1 | ½ PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED 15 H. 03¼ M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: ESAU | | 11 53 | 12 38 | | |
| KNOTS | INITIAL INTERVAL | + 75 | | $\gamma_1$= | $V_1$= |
| 13 SEC. RUN; CORR'N | | + 10 | | $\gamma_2$= | $V_2$= |
| STATION$_2$: GOBY | | 22 63 | 23 48 | | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$: O.K.
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: Tapes filed with tapes for this day 11—9490

| BOMB NO. 1 | PINTS | TIMES (SECONDS) | | DISTANCES (METERS) | |
|---|---|---|---|---|---|
| DROPPED: H. M. | | SCALED | ELAPSED | FOR ASSUMED VELOCITIES ($\gamma$) | FOR FINAL VELOCITIES (V) |
| STATION$_1$: DAGO | | 24 32 | 25 17 | | |
| KNOTS | INITIAL INTERVAL | + 85 | | $\gamma_1$= | $V_1$= |
| SEC. RUN; CORR'N | | + | | $\gamma_2$= | $V_2$= |
| STATION$_2$: | | | | | |

CLEARNESS OF TAPE RECORD, STATION$_1$: O.K. , STATION$_2$:
DEFLECTION, BOMB AMPLIFIER, AT STATION$_1$: , AT STATION$_2$:
REMARKS: 11—9490

CHRON. RATE, MEAN TIME:

TAPES: TIMES: ~~DISTANCES~~:
*Scaled by* J.M.E. *Computed by* J.L.W. ~~*Computed*~~ Times reduced *by* H.H.
*Checked by* J.L.W. *Checked by* J.M.E. ~~*Checked*~~ Plotted *by* H.H.
11—9490

FIGURE 184.—Record of Radio Acoustic Ranging data (double page of Bomb Record reduced about one-half).

with the position number repeated on the right-hand page as illustrated. This provides for four returns, and a fifth and sixth return may be recorded in the horizontal space provided for remarks if this space is not needed for its intended purpose.

The following general instructions shall be followed in recording data in the Bomb Record:

*a. Page heading and day letter.*—Entries in the spaces provided at the top of the page shall be made to agree with those in the Sounding Record. The instructions in **812** and **8121** should be followed. The day letter shall be entered in color as in the Sounding Record.

*b. Position number.*—Different series of consecutive numbers for corresponding positions and bombs shall no longer be used while sounding. The position number as recorded in the Sounding Record shall be entered in the space provided for the "Bomb number." Every care must be exercised to ensure that the position numbers in the two Records agree. To this end position numbers should be communicated between the chronograph station and the plotting station in accordance with **6813.** Position numbers will not run consecutively in the Bomb Record because in R.A.R. many supplemental positions may be numbered in the Sounding Record at which no R.A.R. distances are obtained (see **6812**).

*c. Time of position data.*—The time that the bomb strikes the water is the official time of position. It shall be noted on the clock at the chronograph station and entered in the space provided. The clock shall be compared frequently with the sounding clock, and adjusted if necessary, so that the two clocks never differ by more than a few seconds. (See **6811**.)

*d. Speed of ship, fuse interval, and ship's run correction.*—The speed of the ship (in knots) at the time of the position should be entered in the appropriate space and the fuse interval (in seconds) should be entered in the space immediately below this. The ship's run correction (**6853**(*d*)) is determined from a table and entered in the space provided.

*e. Station names.*—The R.A.R. station names are entered in the spaces provided, in the order of proximity of the stations to the position, the nearest station being listed first. Abbreviations may be used after the first position on each page, initial letters sufficing if there is no duplication.

*f. Initial interval and scaled times.*—The initial interval (**6853**(*b*)) and the scaled time for each station (**6853**(*c*)) are taken from the chronograph tape to hundredths of a second and entered in the "Scaled" column, under the double column headed "Times (seconds)."

*g. Elapsed time.*—The scaled time, initial interval, and ship's run correction should be summed for each station to find the elapsed time (**6853**(*e*)), which is entered in the "Elapsed" column under the double column headed "Times (seconds)." When returns are received from more than two stations, the initial interval and the ship's run correction need be entered only on the left-hand page, their sum being carried over and entered in an appropriate space on the right-hand page.

The clarity of the record on the chronograph tape should be indicated for each station in the space provided below the other recorded data. The amplitude of the sound received at each shore station (**6816**) should also be recorded in the space provided. On the "Remarks" line should be recorded any general information relating to the operation as a whole.

Spaces are provided at the bottom of each right-hand page in which the initials of the persons performing the operations should be entered.

In R.A.R. surveys, buoy stations are frequently located by R.A.R. distances from or to the buoy to be located. These data should be recorded in the Bomb Record and clearly identified by a notation in the margin of the left-hand page, as shown in figure 184.

Bomb positions during a taut-wire measurement for the purpose of determining the velocity of sound experimentally should likewise be identified. Such bomb positions should be numbered so they cannot possibly be confused with position numbers. They should all be indexed on the first or second page following the title page of volume No. 1 of the Bomb Records.

Before a survey controlled by R.A.R. can be plotted, the velocity of sound which is to be used for each distance at each position must be entered in the Bomb Record. These velocities should be entered in the left-hand column under the heading "Distances (meters)"; the right-hand column should be reserved for possible future changes. It is not necessary to enter velocities in the Bomb Record for R.A.R. distances taken for the purpose of locating buoy stations. At some convenient place in the Bomb

Record, preferably at the end of each day's record, the initials of the persons entering and checking the velocities should be recorded.

Distances in meters are no longer used in plotting R.A.R. smooth sheets (see **763**), and need not be determined. All R.A.R. smooth sheets are plotted at an assumed velocity of sound of 1,460 meters per second. Therefore the elapsed times must be converted to account for the difference between the actual velocity of sound and a velocity of 1,460 meters per second. It is necessary to change the actual elapsed times to what they would have been had the velocity been 1,460 meters per second. There are several methods of making this conversion. The increment to be added to the elapsed time (because the actual velocity will almost always be greater than 1,460 meters per second) may be found from the following relation:

$$\text{Increment} = \frac{\text{actual velocity} - 1{,}460}{1{,}460} \times \text{elapsed time}$$

These increments may be determined with sufficient accuracy on a slide rule. Table 36 contains factors by which the elapsed times may be converted into times at the plotting velocity; a computing machine should be used. These factors may also be used to construct a graph or a table of increments for a limited range of velocity. The converted times to be used in plotting the smooth sheet should be entered in the Bomb Record in the spaces to the right of the corresponding elapsed times.

The Bomb Records shall constitute a part of the permanent records of an R.A.R. survey. The volumes shall be numbered separately and consecutively in the proper chronological order. The cover label and title page of each volume shall be completed in accordance with the instructions in **819*b*** for the Sounding Record. The registry number of the survey shall be entered in pencil in the proper space. The total number of bomb positions should be given, followed in parentheses by the number used to control the hydrography.

### *8312. R.A.R. and Dead Reckoning Abstract*

The use of the R.A.R. and Dead Reckoning Abstract (Form 722) is not required for surveys controlled wholly by R.A.R. It is a convenient work sheet, however, which many hydrographers prefer to use for ready reference while plotting the positions on the boat sheet. Some of the entries duplicate the information contained in the Sounding Record. However, it contains the only record of the elapsed times from R.A.R. stations available at the plotting station. The velocity used in plotting each distance on the boat sheet should be entered in the "Remarks" column, or if the same velocity is used in plotting all distances it should be entered at the top of each page.

For surveys controlled wholly by R.A.R., the abstract shall not constitute a part of the permanent records. They should be made available for use by the smooth-sheet plotter, but may be destroyed after the smooth sheet has been verified and reviewed at the Washington Office. They should not be transmitted to the Office.

Occasionally, dead reckoning must be used to supplement R.A.R., as for example on offshore loops (**3371**); in such cases Form 722 must be used, and should accompany the other records of the survey, and be forwarded to the Washington Office. After the survey has been reviewed, the abstracts are destroyed.

Form 722 must always be used in connection with astronomic control and should be forwarded with the other records of the survey when they are transmitted to the Washington Office.

### *8313. Astronomic Sights*

Where sounding lines have been controlled by astronomic sights, recorded observations and computations on Form 719, Astronomic Sight for Hydrographic Control, and the sheets on which the lines of position were plotted, and Form 722, R.A.R. and Dead Reckoning Abstract, shall be assembled in chronological order and bound in a folder and forwarded to the Washington Office. The computations and the plotting sheets for any one hydrographic position should be assembled together.

Smooth copies need not be made of any of the computations or data—the originals, if legible, will suffice.

The use of Form 719 for the computation of astronomic sights is explained in **3382** and the plotting of morning and evening star sights on separate sheets is described in **3387**.

No written report need accompany these records unless the observations have been used for unusual purposes, or methods not described in this Manual were used in adjusting the sounding lines to the lines of position.

## 832. CONTROL RECORDS

In addition to the control stations located by triangulation and topography, supplemental stations must often be located by hydrographic methods for use during the hydrographic survey. This is particularly true of offshore surveys, where buoy stations are always located by the hydrographer. The observations taken to locate such stations must be recorded permanently and the record, together with the associated computations, must be transmitted to the Washington Office with the smooth sheet. These are the sole records of the data used in determining the positions of the buoy stations, and they form a part of the permanent records of the survey.

The location of buoy stations requires a large amount of varied observation data and computations. Such control records may be conveniently grouped as follows:

(*a*) Buoy stations located by direct reference to shore control and the necessary computations (see **8322**).

(*b*) Observations and computations of buoy traverses (see **8323**).

(*c*) Buoy stations located by R.A.R. distances (see **8324**).

A buoy-controlled hydrographic survey may require only the control records listed in (*a*), or records listed in (*a*), (*b*), and (*c*) may be required, depending on the method of establishing the control and the type of survey. In any case the records and computations should be separated into these three categories for transmittal to the Washington Office. A notice "Not for Geodesy" should be included in each package of such records, so that they will not be sent to the Division of Geodesy when received at the Office.

Typed copies of these control records and computations are not necessary; the original copies in pencil, if legible, will suffice. All of the computations must be on letter-size paper or be folded to that size for facility of storage in the archives. Only the accompanying report, when required, and the list of buoy station locations in the Descriptive Report (**8435**) need be typed.

### *8321. Station Locations by Sextant*

Sextant observations to locate a few supplemental stations may be recorded in the Sounding Record with the hydrography (see **248** and **8146**), but whenever a considerable number of stations are so located by the hydrographic party the obser-

vations that are taken to locate them should be recorded in a separate sounding volume or notebook. This record is often used by personnel who were not associated with the field work, so it is essential that the record be complete, clear, and self-explanatory.

The observations taken to locate each shore station or buoy station must be clearly identified and the manner of recording should be as specified in this Manual.

Observations to locate topographic detail and to determine elevations for drawing form lines from the ship, as described in **382**, may be recorded in this same volume.

All data contained therein shall be indexed on the front pages of the volume.

This volume shall be labeled "Station Locations by Sextant" and shall be numbered as one of the Sounding Records (see **819**) and shall be forwarded with them as part of the permanent records of the survey.

### *8322. Buoy Locations*

All of the computations to determine the positions of buoy stations by observations on shore stations shall be bound together in one folder and plainly identified on the outside. An abstract of all computations involved in determining the position of each buoy station shall be made and placed in the front of the folder. Each sheet of computations should be headed "For location of station____________" and these, together with the position computations, should be assembled together in the folder.

A written report need not accompany the records of buoy locations, unless some new method is used which requires an explanation. When this is deemed advisable by the hydrographer, a short typewritten report should be prepared and placed in the folder with the abstract of computations.

The observations to locate buoy stations are recorded in a separate sounding volume or notebook (see **8321**) and this is transmitted with a Sounding Records—not with these computations.

The folder should contain, for each buoy station located, computations on at least the first three and sometimes on all of the following forms:

Computation of Three-Point Problem, Form 655.
Computation of Triangles, Form 25.
Position Computation, Third-Order Triangulation, Form 27.
Reduction to Center, Form 382.
Inverse Position Computation, Form 662.
Azimuth by Inclined Angle, Form 720.

Where observations to locate buoys are made at shore stations, they should be recorded in Form 250, Observations of Horizontal Angles, or in Form 251, Observations of Horizontal Directions, and this record should be transmitted with the computations.

### *8323. Buoy Traverses*

Where buoy stations are located by traverse—by taut-wire or log distances—numerous records and computations are required to determine the final positions. For transmittal to the Washington Office these records and computations shall be bound in three separate folders, each being appropriately identified on the outside, which shall contain the following:

(1) $\left\{\right.$ Abstract of Buoys Planted, Form 714.
Taut-Wire Traverse Observations, Form 777.
Log runs to measure distances (recorded on Form 777).

(2) Abstract of Buoy to Buoy Azimuth, Form 718.
Azimuth by Inclined Angle, Form 720.

(3) Position computations (Form 27).

Insofar as possible, the records and computations for each buoy station shall be assembled in the folders in the order in which the traverse was computed.

A short report should be typewritten on letter-size paper and be forwarded with the records and computations. In it the details of the traverse should be briefly described under the following headings, insofar as applicable:

A. *Project.*—The proper number should be given, and the method used to control the hydrography should be described briefly.

B. *Layout of scheme.*—The general layout of the scheme of control buoys should be explained, unusual features of the scheme should be described, and any influencing factors should be discussed.

C. *Determination of positions.*—The method of locating each tie-in buoy station and each buoy station not in the traverse should be given. Where a method described in this Manual is used, it may be identified simply by the proper reference number.

D. *Traverse closures.*—For each traverse, the length of the traverse, the total closing error (in meters), and the closing error (in meters) per statute mile, shall be tabulated. The average closing error per statute mile for all the traverses shall also be given. Any method or expedient used in the computations or adjustment of the traverse to reduce the error of closure shall be explained.

E. *Statistics.*—The following statistics should be included:

Number of buoy stations located by observations on shore stations.
Number of buoy stations located by traverse.
Number of buoy stations located by observations on traverse stations.
Total number of buoy stations located.
Number of sun azimuths observed.
Total length of traverse (in statute miles).

The above report need not include any description of the buoys used, the method of anchoring the buoys, the field methods used, or any other such details, for they will be apparent from the other information given.

The following records should be bound with and be made a part of the report:

a. *Sketch of buoy-control scheme* on letter-size paper or tracing cloth. The relative positions and the names of the buoy stations of the traverse should be shown, and the relative positions of the shore stations (names are not necessary) used in locating the tie-in buoy stations. The approximate limits of the area surveyed should also be delineated.

b. *Record of log tests* (see **4454**).

c. *Record of taut-wire calibration* (see **4467**).

d. *Traverse adjustment* (see **944**).

### *8324. Locations by R.A.R. Distances*

Buoy stations are frequently located by R.A.R. where the survey is controlled by R.A.R. and stations are required far offshore. The forms on which the data are tabulated, Form 713, Buoy to Buoy Distances by Bomb, and Form 715, Abstract of Bombed Distances, should be arranged in chronological order and bound in a folder for transmittal to the Washington Office.

A short typewritten report should be included. The report should describe briefly the methods used to determine the positions; and if by a graphic plot, the scale of the projection should be given. Where the distance arcs to any station do not intersect near a point, and a position is accepted based on unequal weighting of the measurements, the reason for this must be stated. The graphic plot should not be sent to the Office but it should be retained until the hydrographic survey has been verified and reviewed.

## 833. Velocity of Sound Records

For hydrographic surveys utilizing echo sounding or R.A.R., a knowledge is required of the velocity of sound in the water surveyed. The values to be used are based on water temperature and salinity observations made in the area, or on special tests, and these form a part of the record of almost every hydrographic survey.

### *8331. Temperature and Salinity Observations*

The observations of water temperatures and salinities are recorded on Form 717, Record of Temperatures, Salinities, and Theoretical Velocities (see **6341**), and the temperature and salinity graphs are plotted on Form *B*-1528-5, Graph of Temperatures and Salinities (see **6342**). These forms, or the temperature curves derived from the bathythermograph slides (**473**) if that instrument is used, shall be arranged in chronological order and bound in a separate folder for transmittal to the Washington Office. The contents shall be appropriately identified on the outside of the folder. A written report is not required.

The temperature and salinity curves should be inked and a typed copy should be made of the record of observations, unless they were recorded in black ink originally, so that photostat copies can be made for interested persons.

### *8332. Velocity Corrections*

Velocity corrections (**561**) are determined for limited areas in which, and periods of time during which, the physical characteristics of the water are relatively stable, so that mean values will suffice for use in correcting echo soundings. For each area and period of time, mean regional temperature and salinity curves must be drawn, from which the curve of velocity corrections (**5614**) may be derived by either the numerical or the graphic method (see **5613** and **5615**). These curves and computations should be clearly identified as to applicable area and time, assembled in sets in chronological order, and bound together in a folder for transmittal to the Washington Office. The originals will suffice—neither typed copies of the computations nor smooth copies of the curves are required.

The method of computing velocity corrections has been standardized and a written report is not required unless, for some reason, the hydrographer finds it necessary to use a method not described in this Manual. In such case a short report explaining the method and giving the reason for using it should accompany the curves and the computations.

The records of simultaneous comparisons (see **5522**) should also be included in this folder, together with any tests of other sounding apparatus applicable to the equipment used in the survey.

### *8333. Horizontal Velocity for R.A.R.*

An abstract of the results of the tests to determine the apparent horizontal velocity of sound should be transmitted to the Washington Office with the records of an R.A.R. survey. The abstract should be a tabulation of the elapsed times measured and the corresponding horizontal distances, measured or computed, from which the apparent velocities were derived. The date and time of each test shall be given. The method by which each horizontal distance was determined shall be indicated.

Any computations made to determine horizontal distances where the bomb positions are fixed by sextant angles and any computations made to determine the velocity of sound indirectly (see **6353**) should be retained until the hydrographic surveys have been verified and reviewed, but need not be forwarded to the Washington Office.

A comprehensive report should be forwarded explaining how the horizontal velocities used in plotting the smooth sheet were determined, referring to **6361** and **6362**, and the method used should be justified. The report should contain a discussion of the accuracy of the results, and any particular difficulties should be elaborated on. Any special methods of application should be described in full.

### 834. Survey Data of Other Organizations

The records of survey data of other organizations which should be submitted with other records are of the following several classes:

(*a*) Control data of triangulation schemes which have been connected to the federal network of triangulation by the establishing agency, a record of which is not in the Washington Office (see **216**).

(*b*) Control data of triangulation schemes which are connected to the federal network by the survey party (see **224**).

(*c*) Hydrographic surveys made by other organizations, which are not duplicated by the survey party, but with which a junction is made (see **3131**).

(*d*) Hydrographic surveys made by other organizations, which show changes or are of more recent date than those on which the charts of the area are based.

(*e*) Maps or blueprints from other sources which are submitted to supplement a topographic survey of this Bureau (see **2361**).

(*f*) Maps or blueprints from other sources which show changes which have taken place in the areas, useful for chart correction.

With respect to (*a*) and (*b*), descriptions of stations, geographic positions, and a sketch of the triangulation are required. Copies of the hydrographic surveys in (*c*) must be forwarded with the other records of the hydrographic survey, unless there is reasonable assurance that copies are already in the Office files, in which latter case they must be unmistakably referred to by an identifying number. With respect to (*d*), (*e*), and (*f*), copies of the surveys must be furnished in each case.

Copies of the maps and surveys in (*c*), (*d*), (*e*), and (*f*) are useless unless each is on an accurate projection by which it can be correlated with the work of the Bureau, or unless each contains at least three points whose geographic positions are known (see **2361** and **3131**).

Copies of surveys or maps in (*d*) and (*f*) should be forwarded only after proper evaluation as to their usefulness and accuracy has been made by the field party. To be of value they must show; first, information of a nature suitable for charting, and second, only projects actually completed. The surveys must be of sufficient accuracy to permit their application to the chart without undue forcing. The Chief of Party shall state over his signature the fact that an examination has been made on the ground and that the actual existing conditions have been noted on the plan; the date of the examination shall be shown.

With respect to (*e*) and (*f*), features that are of use to the navigator as landmarks are important and must be located by the field party independently from the plan.

### 835. Completion of Records and Reports

It should be the aim of the Chief of Party to forward all field records and sheets in a condition as nearly completed as the circumstances permit. Before forwarding,

he shall inspect thoroughly each sheet and Descriptive Report, and in a general way the accompanying records. Any deficiency must be fully explained. All results of field work shall be forwarded to a Processing Office or to the Washington Office as soon as practicable after the completion of the field work and, unless otherwise authorized, before the beginning of another project or another season's work.

### *8351. Data To Be Forwarded*

For convenient reference there is given herewith a summary of the data to be forwarded to the Washington Office in connection with different types of hydrographic surveys. This list should be consulted before the records and reports are prepared for shipment. (See also **859**.)

#### A. FOR EVERY HYDROGRAPHIC SURVEY

Smooth sheet:
- Hydrographic title sheet (Form 537).
- Tracings of junctions of adjoining surveys.
- Overlay tracings of congested areas.

Boat sheet:
- Tracings of transfer of topography.

Sounding Records (Form 275):
- List of control stations.
- Record of cuts to hydrographic signals (if recorded separately).

Wire-drag records (Form 411).

Descriptive Report:
- Statistics.
- Tide note.
- Geographic name list.
- Buoy station locations.
- List of wire-drag groundings.
- Approval sheet.

Descriptions of hydrographic stations (Form 524).

Recovery of topographic and hydrographic stations (Form 524).

Tide records (as available):
- Report of establishment of tide station (Form 681).
- Marigrams.
- Tide tabulations and computations.
- Leveling record, tide station (Form 258).

#### B. ADDITIONAL FOR ECHO SOUNDING

Fathograms.

Record of temperatures, salinities, and theoretical velocities (Form 717).

Bathythermograph record of serial temperatures.

Graphs of water temperatures and salinities (Form B-1528-5).

Computations of velocity corrections.

Velocity correction curves (Form J-100-5).

Velocity correction abstract (with Descriptive Report).

Overlay tracings showing silted areas.

#### C. ADDITIONAL FOR RADIO ACOUSTIC RANGING

Bomb Records (Form 670).

Record of tests to determine apparent horizontal velocity of sound in sea water.

Report on horizontal velocity for R.A.R.

Record of locations of R.A.R. stations.

Tracings of dead-reckoning plots.

Report on buoy stations located by R.A.R.

#### D. ADDITIONAL FOR TAUT-WIRE MEASUREMENTS AND BUOY CONTROL

Abstract of buoys planted (Form 714).
Buoy-to-buoy distances by bomb (Form 713).
Abstract of bombed distances (Form 715).
Azimuth by inclined angle (Form 720).
Abstract of buoy-to-buoy azimuths (Form 718).
Astronomic sights for hydrographic control (Form 719).
Plotted lines of position.
Position computations (Form 27).
Geographic positions of buoys (Form 28B).
Buoy station locations (with Descriptive Report).
Calibration of taut-wire apparatus.
Taut-wire traverse observations (Form 777).
Report on buoy traverses.
Record of cuts to locate buoy stations.
Record of log tests.
Logs of runs to locate buoy stations by log (Form 777).

#### E. ADDITIONAL FOR ASTRONOMICALLY CONTROLLED SURVEYS

Astronomic sights for hydrographic control (Form 719).
Plotted lines of position.
R.A.R. and dead reckoning abstract (Form 722).
Record of log tests.

#### F. AREA REPORTS

Landmarks for charts (Form 567).
Positions of fixed aids to navigation (Form 567).
Coast pilot notes.
Geographic name report.
Chart for United States Coast Guard.
Progress sketches.
Triangulation station descriptions (Form 525).
Triangulation station recovery notes (Form 526).
Current observations (Form 270):
    Abstract of currents observed (Form R-233).
Magnetic declination records (Form 38a):
    Observations and computation of compass deviations (Forms 354, 355, and 356).

### 836. Shipment of Records

Form 413, Letter Transmitting Field Records, shall be used to transmit all hydrographic records to the Washington Office, the original and one duplicate being mailed in a separate envelope.

Sheets and records, when forwarded by mail, should be well wrapped and registered. Packages weighing less than 4 pounds each may be mailed under frank, and registered by payment of the registry fee only. Any number of packages may be mailed at one time. Packages weighing between 4 and 70 pounds cannot be mailed under frank and registered; parcel post postage plus the registry fee must be paid. Such packages are handled with the same care as though sent first class. The smooth sheet, boat sheet, and Sounding Records shall be mailed at different times as security against total loss of the survey records.

When sheets and records are forwarded to the Office, each package of a season's work shall be numbered consecutively, beginning with No. 1 and continuing until all data for the season have been forwarded.

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The number of each package and a list of its contents, with a reference to the registry number of the survey, shall be noted in the transmittal letter. A carbon copy of Form 413 transmitting the records shall be included in each package.

Records and computations destined to divisions other than the Division of Charts should not be included with hydrographic data on the same copy of Form 413.

Sounding Records and other data should be duplicated only when specifically directed or when there is considered to be an unusual risk in the method of forwarding. (See also **326** and **796**.)

## 84. DESCRIPTIVE REPORT

A Descriptive Report shall be written and submitted to accompany each hydrographic sheet. A separate Report for each sheet is preferable, but where much of the information, such as control data and survey methods, is common to several sheets, as in launch surveys, one Report may be submitted for two or more adjoining sheets of a season's work. Where separate Reports are submitted, cross references can be utilized to avoid repetition of parts of the text.

The purpose of the Report is to supplement the smooth sheet and Sounding Records by information that cannot be shown graphically on the smooth sheet or to direct attention to important results. It outlines the conditions under which the work was done. It should be written with a view to assist the cartographers who verify and review the survey and chart the results. It serves to index all records and reports which are applicable to the survey, and to give, in concise form, information on certain standard subjects. The Descriptive Report should, therefore, be written with these purposes in mind. General statements, as well as the detailed tabulation of self-evident data, such as inshore rocks and shoals, or rocks or coral heads that are encircled by depth curves, serve no purpose and should not be included.

A daily journal should be kept by the hydrographer, in accordance with **385**, as a satisfactory Descriptive Report cannot be written from memory nor by an individual having no personal knowledge of the field work unless he has such a carefully prepared journal.

Notes made on the boat sheet to supplement the daily journal shall, if applicable, be incorporated in the Descriptive Report.

In surveys of large extent or of a complicated nature, it may be advisable to write special reports on certain phases of the work covering the entire season or area. A cross reference to each of these should be made under the proper heading of the Descriptive Report.

The Descriptive Report of a limited isolated survey should include all data, computations, forms, etc., ordinarily mailed as separate reports, with the exception of those specifically required to be submitted separately, such as coast pilot notes and landmarks for charts.

### 841. Sequence of Contents

The various data which are required on separate sheets shall be arranged before and after the text in the sequence described herein.

#### *8411. Descriptive Report Title*

Form 504, Descriptive Report, shall be used as the outside cover sheet, all of the appropriate entries being made.

### *8412. Title Sheet*

Titles shall not be placed on hydrographic sheets by the field party. But the information for the title of a survey shall be furnished on Form 537, Hydrographic Title Sheet. One copy shall be forwarded attached to the smooth sheet, and one copy shall be inserted in the Descriptive Report. Entries shall be made in all applicable spaces on the form. The title of a hydrographic survey must clearly indicate the limits of the survey and agree with the entries in the Sounding Records. The information shall include the specific locality, year of the survey, the names of those persons actually in charge of sounding, the depth unit, and the plane of reference. (See **9322**.)

### *8413. Index of Sheets*

Where there are a number of sheets in one project, an admirable practice is to make an index of these on a small-scale outline map, on which the limits, numbers, and scales of the various sheets are shown. Where this is done, a copy should be inserted in the Descriptive Report, with the specific survey crosshatched or otherwise indicated, as it is of considerable assistance to the cartographers and others using the records. The scale of the index is immaterial, but the size of the paper should be 8 by 10½ inches. It may be prepared at an enlarged scale for reduction and multilith reproduction in the Washington Office, or drawn on tracing cloth at the final scale for ozalid prints. In addition to the limits of sheets of the project it should include any junctions with prior surveys. Prior surveys in the area may also be outlined if this can be done without confusion.

## 842. DESCRIPTIVE REPORT TEXT

The text of the Descriptive Report shall be typewritten on letter-size paper with a left-hand margin of at least 1 inch. It need not be submitted in duplicate.

Each text shall be entitled "Descriptive Report to Accompany Hydrographic Survey H-_______ (Field No._____________)" (*insert registry and field numbers*) and shall include the title and year of the survey. At the top of the page shall be given the scale of the survey, the names of the Chief of Party and the major survey vessel, and the name of the officer in immediate charge of the field work, if other than the Chief of Party.

The text should be written clearly and concisely, and according to a standard form. It is intended to supplement and not duplicate the information which is more clearly evident on the smooth sheet. Methods and instruments may be identified and verbose explanations avoided by use of the reference numbers in this Manual. Wherever reference is made in the text of the report to a feature on the smooth sheet, the latitude and longitude shall be given. The text shall be arranged under the following lettered headings and in the order appearing here, omitting any inapplicable headings.

*A. Project.*—Include the project number and date of original instructions, and the dates of any supplemental instructions and letters which are pertinent. Give also the addressee of the instructions and letters if they are addressed to a person by name. (See **121**.)

*B. Survey limits and dates.*—Give the general locality and limits of the survey and refer to the index of hydrographic sheets if one is included. Give the dates of beginning and ending field work. If the survey makes a junction with prior surveys, mention these by registry numbers, dates, and scales; and if an index of sheets is not furnished, list by registry numbers all contemporary surveys with which junction is made.

Include any remarks about the progress of the work, explaining especially the reason for any unsatisfactory progress.

*C. Vessel and equipment.*—Identify the vessel or vessels actually used in the survey and give the general area in which each operated. If the survey was made from launches, state whether they operated from the ship, from a camp, or from a shore base, giving the locality or localities of the latter.

Give the turning radius of each vessel at the speeds at which each was operated during hydrography in accordance with **3463**.

Identify by types and serial numbers all echo-sounding instruments used, give the type of other sounding equipment used, and the general area or depths in which each was used.

*D. Tide and current stations.*—Give the location of the tide station and any time or range corrections which were applied to the tidal data in reducing the soundings. If more than one tide station was used, identify specifically the parts of the survey to which each applies.

List the current stations if any were occupied.

*E. Smooth sheet.*—State where and how the projection was made, whether by hand or by ruling machine, and how the shoreline and signals were transferred if unusual methods were used, as for example, those described in **7331** and **7334**.

State whether the transfer of shoreline and topographic details has been verified in accordance with **757**.

*F. Control stations.*—Give the source of the control for triangulation stations; give the name of the Chief of Party, and the year of location. For topographic stations give the registry numbers and years of the topographic sheets from which the positions of the stations were taken, identifying the method used on each; that is, planetable, air photographic, or graphic control.

Where survey buoys were used for control, explain in detail the method used to locate them unless a special report has been made (see **832**), in which case a mere mention of the method of control and a reference to the report will suffice.

Explain in detail any special or unusual methods used to locate any control stations, identifying them by name. If the positions of the control stations in any part of the area are less accurate than in other parts, or if any specific stations are less accurate, identify these by area or by name, giving the reason for the deficiency and a statement as to what effect this may be expected to have on the position accuracy of the soundings.

*G. Shoreline and topography.*—Give the source of the shoreline and topographic details, identifying topographic surveys by number and year. If any of the shoreline or topographic details were found to be inaccurate or to have changed since the original survey and were revised by the hydrographer, identify specifically the parts revised, giving reasons for revision and complete details of the methods used. (See **381** and **753**.)

Any discrepancies between the topographic and hydrographic surveys which had to be adjusted should be explained in detail in accordance with **7827**.

If the survey is of an area where there is no prior topographic survey and the hydrographic party furnishes these details, a statement should be made as to their accuracy and the methods used, and whether they are adequate for charting (see **3812**).

If the low-water line is not defined by the soundings, describe the conditions that prevented this. (See **3122**.)

*H. Soundings.*—State the methods by which the depths were measured, describing in detail any unusual methods or equipment and any unusual corrections that were applied to the recorded depths.

*I. Control of hydrography.*—State the methods of horizontal control used and define the different areas in which each was used. Explain in detail any unusual or substandard methods. If any part of the work had to be adjusted in horizontal position give the reason and the method of adjustment used.

If R.A.R. control was used explain in detail the method of determining the velocities used and the method of plotting, unless this is included in a special report (**8333**) to which reference may be made.

*J. Adequacy of survey.*—State whether the survey is complete, and whether it is adequate to supersede prior surveys for charting. Identify any part of the survey that is incomplete and state in detail what is required for completion. Identify any part of the survey that is less reliable than the remainder or that fails to comply strictly with the requirements of the Hydrographic Manual or of the project instructions, giving the reasons in each case.

State whether the junctions with the adjoining surveys are satisfactory or whether *holidays* or excessive differences exist. State also whether the depth curves can be adequately drawn at the junctions.

Mention any nonstandard depth curves used to define special submarine features.

*K. Crosslines.*—State the percentage of crosslines run and give discrepancies at crossings in percentages of the depth; a list tabulating each crossing is not required except for surveys controlled by R.A.R. (See **3571** and **7722***a*.)

*L. Comparison with prior surveys.*—Compare the results of the new survey with those of prior surveys in the area, identifying the latter by registry numbers, dates, and scales. (See **3234** and **3521**.) State the general agreement or disagreement between the new survey and prior surveys; describe, in general, investigations made of any discrepancies found and give conclusions reached as to the reasons for the discrepancies.

List in tabular form any features or depths on prior surveys whose existence has been disproved, and which should be deleted from the charts. Include in the list bare rocks, as well as subsurface features and depths.

Discuss the agreement or disagreement in depths at junctions with prior surveys and if an adjustment is required, make a recommendation as to how this is to be effected. (See **3132**.)

Compare the new survey with any surveys in the area by the United States Corps of Engineers. Since these are generally not duplicated, the discussion will ordinarily be limited to the agreement or disagreement at the junction. The Engineers surveys should be identified by date, scale, and sheet number and, unless copies are known to be available in the Washington Office, those with which comparison is made should be forwarded with the smooth sheet.

*M. Comparison with chart.*—Compare the new survey with a copy of the largest-scale chart of the area, identifying the chart by its print date and give similar information, without duplication, to that required for the prior surveys. Dangers, shoals, and wrecks are often charted from sources other than the surveys of the Bureau and it is important that definite recommendations be made as to the disposition of differences between the new survey and the chart. This comparison shall be made, regardless of any difference in scale between the new survey and the chart. If the comparison required in *L* has been made, most of the charted data will already have been considered. If the comparison required in *L* has not been made, this comparison with the chart shall be complete and detailed. (See **3522**.)

*N. Dangers and shoals.*—Tabulate and describe the *important newly found* dangers and shoals, giving the latitude and longitude of each, and the least depth on each with its position number.

Complete information should be included in the Sounding Record regarding the extent of development, including the time spent in drift sounding over an area or in watching for breakers. This information should not be repeated in the Descriptive Report except in special cases. (See **3666**.)

Reported uncharted dangers and shoals should be discussed fully giving the depths found and the area covered and time spent in search for any reported danger not found.

Dangers and shoals found with the wire drag but not cleared should be listed, with the least depth found in each case and additional information as required above.

List charted dangers or shoals, or those shown on prior surveys on which the least depths are less than those found on the new survey. Discuss each case separately as to the adequacy of the new data and make a recommendation in each case as to whether the previous depth should be retained. (See **352** and **363**.)

Mention specifically each danger reported to the United States Coast Guard in accordance with **8522**.

Include a statement that all charted dangers, shoals, and bare rocks were found as charted, or shoaler depths were found except for those listed in *L*, *M*, and *N*.

*O. Coast pilot information.*—Information included under this heading shall be repeated in a special coast pilot report in accordance with **912**, or an extra copy should be furnished and marked for the Coast Pilot Section. (See **159**.)

List any areas recommended as anchorages in newly surveyed areas and give the following information: depth of water; holding quality of the bottom; ranges or bearings for entering or anchoring; protection from wind, sea, and currents; the availability of fresh water; and the extent used by the survey ship and other vessels.

List the places where the ship or launches anchored while making the survey and give information similar to the above insofar as it is applicable.

Describe natural channels that can be used for navigation. Give recommended courses and the controlling depth and its location in each, according to the new survey. Give controlling depths and their locations in all artificial channels. Recommend courses for navigating any part of the area for which this information is available.

Describe all useful ranges, bearings, and other marks for clearing dangers or passing close by or over them and the best courses across bars in accordance with **356**.

Describe the prevailing weather in the area for the period of the survey if it is a little-known area; otherwise, describe only weather conditions differing from normal.

Describe the currents encountered in the area (the average and maximum experienced) and give their directions, and state the basis of the information if current observations were not made.

Mention any wrecks or obstructions which are dangerous to navigation (see **365**).

*P. Aids to navigation.*—The positions of fixed aids to navigation shall be reported on Form 567 in accordance with **8532**. A reference to this report shall be made.

List all floating aids to navigation located, using the exact nomenclature given in the Light List, and give the latitude and longitude of each, the depth of water at each, the position number or numbers of the location data, and the date of location. (See **784** and **8531**.)

Mention specifically any aids to navigation whose positions or characteristics differ materially from those on the charts or in the most recent edition of the Light List (see **784**).

A reference shall be included to any report made during the field season directed to the United States Coast Guard relative to aids to navigation. (See **3832** and **853**.)

List the azimuths of all ranges maintained for navigation that were determined in connection with the survey. (See **3833**.)

List all unofficial aids to navigation stating their purpose, whether maintained and by whom, and whether such maintenance is seasonal or not, if this is known. Give the position and a description of each aid, and the date of establishment if known. (See **3834**.)

List the overhead clearances of all bridges and telephone or telegraph lines over waterways (see **3836**). State whether each was measured, estimated, or obtained from the "List of Bridges over the Navigable Waters of the United States" published by the United States Corps of Engineers. Discuss any discrepancies between the field data and that found in the above publication.

Mention any submarine cables and ferry routes within the area and give the positions of their termini (see **7847** and **7867**).

*Q. Landmarks for charts.*—Data relative to landmarks for charts shall be submitted on Form 567 on an area basis. (See **155**.) A reference to this report shall be made here, with a list of the recommended landmarks within the limit of the survey, but no other data are necessary. (See **8534**.)

*R. Geographic names.*—A special report on geographic names is required (see **163** and **856**) to which reference shall be made under this heading. The reports required on this subject are fully described in section **16**. If a special report has been recently submitted or will be submitted it should not be duplicated here, but it should be supplemented by (1) any additional information which has been discovered, and (2) recommendations for naming important previously unnamed features. (See **164**.)

If the one survey constitutes the entire season's work, all of the information required on geographic names may be included here rather than in a special report. (See also **8433**.)

Any geographic names which are found to apply to areas of indefinite extent should be discussed under this heading and not shown on the smooth sheet.

*S. Silted areas.*—Where silted areas are detected by the use of an echo-sounding instrument, a full discussion shall be included as to the frequency and size of the areas and their apparent thickness. (See **7831**.)

*T. By-product information.*—Give any information of scientific or practical value resulting from the survey or from special investigation or observations made. If special reports of this nature have been submitted they should be referred to under this heading by title and author. (See **1134** and **8585**.)

*U.–Y. Miscellaneous.*—Include under these letters other information which should be included in the Descriptive Report in special cases. (See for example **8434**.)

*Z. Tabulation of applicable data.*—Include a complete list of data connected with the hydrographic survey, including all forms, records, and special reports which are not made a part of the Descriptive Report and excluding, of course, Sounding Records and Bomb Records. Give the date each was forwarded to the Washington Office. (See sections **83** and **85**.)

## 843. SEPARATES FOLLOWING TEXT

Various tabulations and kinds of information are required on separate sheets of paper inserted in the Descriptive Report. Each of these that is applicable shall be furnished, inserted in the order in which it is described in the following items.

Beginning with the first page of the text, it and the attached inserts shall be numbered consecutively, ending with the approval sheet (**8437**) which is always placed last.

### *8431. Statistics*

An abstract of statistics of field work shall be made for each hydrographic survey and attached to the Descriptive Report. The sheet should be headed "Statistics for Hydrographic Survey H-____________" (*insert here registry number of sheet and year of survey in parentheses*), followed by the name of the vessel and the project number. The statistics should be arranged by days, giving for each day, the volume number or numbers, the day letter, the date, the number of handlead and wire soundings, the number of positions, and the number of statute miles of sounding. Totals for the survey should be given, including the total number of square statute miles of sounding. All statistics should be given in standard units (see **124**).

Where two or more vessels are used on one hydrographic survey, the statistics for each should be shown separately.

### *8432. Tide Note*

A tide note, on a separate sheet of paper, shall be furnished for each survey and included in the Descriptive Report. The location, including the latitude and longitude, of each tide station used for reducing the soundings plotted on the sheet shall be given. If more than one station was used, the tide note should define the limits of the area in which each was used. This note should also state the height of the tide staff at each station corresponding to the plane of reference and whether any corrections for differences in time or height were applied to the observed tides. If the hourly heights were furnished from the Washington Office the tide note should so state. Should the same tide note be applicable to more than one survey, a copy of the original note shall be included in the Descriptive Report of each.

### *8433. Geographic Name List*

An alphabetic list of all the geographic names penciled on the smooth sheet shall be prepared separately and inserted in the Descriptive Report (see **165**). The list may be arranged in two columns, if there are many names, provided there is a blank space of 1½ inches to the right of each column for Office entries (see **9321**). No other information should be included with this list, except references to any special reports on the subject and to the pages of text of the Descriptive Report, where geographic names are discussed. (See also section **16**.)

### *8434. Velocity Correction Abstract*

An abstract, in tabular form, of the velocity corrections which were applied to the echo soundings shall be included as a separate entry, for each survey where echo soundings are used. These corrections will generally be derived from the correction curves which are submitted with the special report on the velocity of sound (see **833**). If a special report is not submitted, a detailed explanation of the derivation of the corrections shall be furnished under one of the *U* to *Y* headings in the Descriptive Report. (See also **561**.)

If different corrections were applied through different time periods, the abstracts shall indicate clearly to which periods each abstract of corrections is applicable. If

the same corrections are applicable to several surveys, a copy of the data shall be included in each Descriptive Report.

### *8435. Buoy Station Locations*

Where buoy stations or R.A.R. stations were used and final positions of these have been derived other than by plotting on the smooth sheet, an alphabetic list shall be prepared giving the correct latitude and longitude of each station. If two or more buoy stations in close proximity to each other were used, the inclusive dates between which each was used shall be noted.

A concise reference to the method of location, the records containing the observed data and the computations, and to the special report which contains the buoy location data, if one was submitted, shall be added. (See **832**.) No other data should be included on this separate insert.

### *8436. Miscellaneous*

After the abstract of buoy locations and before the approval sheet there shall be inserted any other data which are believed to be an essential part of the records. If these are voluminous they should be bound separately in their proper groups (see section **83**) and forwarded with the records of the survey, but should not be included in the Descriptive Report. Examples of such are the original observations, computations, and plotted lines of positions of astronomic sights; the computations of buoy stations; the velocity of sound tests; and the computations of taut-wire traverses. Smooth copies of these are not required—the originals will suffice—nor is it necessary to ink the originals (see for example **3382**).

### *8437. Approval Sheet*

The Chief of Party shall furnish on a separate sheet of paper, attached to the Descriptive Report, a signed statement of approval of the survey. This shall serve as a general approval of the smooth sheet and all accompanying records (see **3411** and **7941**). It should include a statement as to the amount of personal supervision of the field work and the frequency with which he examined the boat sheet, whether the survey is complete and adequate, whether additional field work is recommended, and any additional information not included in the Descriptive Report that may be of assistance to the Office in reviewing the survey.

When a hydrographic sheet is transferred elsewhere for completion, in accordance with instructions from the Office, approval shall be made of only that part of the smooth plotting completed at the time of transfer. If the completed smooth sheet is returned to the Chief of Party for examination prior to transmittal to the Washington Office, his approval of the entire sheet should then be added.

## 844. ADDITIONS AT WASHINGTON OFFICE

Between the receipt of the hydrographic sheet and accompanying records at the Washington Office and the final approval of the survey by the administrative officers, certain forms and reports are added to the Descriptive Report, in the order referred to below. The purpose of each addition is briefly stated.

*a. Records accompanying survey and Office statistics.*—On this form an entry is made of the records accompanying the survey, such as, the number of boat sheets, sounding volumes, and wire-drag volumes, but this is in no sense a list of the data required in **842Z**.

On the same form there are included certain Office statistics incident to the verification and review of the survey, such as, names of the verifier and reviewer, the time required for the Office completion of the survey, and the amount of revision made to the sheet during verification.

b. *Immediate attention routing.*—As soon as a Descriptive Report is received at the Washington Office it is examined and routed to sections for immediate attention to any specific information therein. Form *M*-238 is used.

c. *Tide note.*—The Records are examined, insofar as tide reducers are concerned, in the Division of Tides and Currents. A memorandum is prepared, approving the plane of reference for the hydrographic survey, based on the information included in the tide note submitted with the Descriptive Report (see **8432**). There are also given the final value of the plane of reference (sounding datum) in relation to the tide staff and bench marks, and the height of the plane of mean high water above the plane of reference. Attention is called to any deficiency in the tide records. Form 712, Tide Note for Hydrographic Sheet, is used for this memorandum and is substituted for the original tide note, which is discarded. (See **9323**.)

d. *Review.*—A report is written by the cartographer who reviews the survey. This report compares the results of the survey with prior surveys in the area and with the charts, calls attention to any deficiencies, and lists additional work which should be done. The report is inspected by the Assistant Chief of the Surveys Branch, and is approved in writing by four administrative officers. The original of this report is inserted in the Descriptive Report, and a copy is sent to the Chief of Party under whose direction the field work was done. (See **9348** and **935**.)

### 845. Deficiencies in Former Descriptive Reports

Important deficiencies in Descriptive Reports submitted in the past have been:

(*a*) The report consisted mainly of general statements of self-evident information.

(*b*) Important charted soundings were not mentioned individually nor was definite recommendation made for their disposition.

(*c*) The time spent on the investigation of differences between the new survey and prior surveys was not given.

(*d*) The Descriptive Report was not signed by the hydrographer or was not approved by the Chief of Party.

(*e*) References to United States Engineers blueprints did not include the survey numbers and dates.

(*f*) Bridge clearances were not compared with charted or published values, or recommendations were not made as to the best disposition of differences.

(*g*) No mention was made of overhead cables, submerged cables, transmission lines, etc.

(*h*) No comparison was made with the published chart or with prior surveys because of differences in scale.

## 85. MISCELLANEOUS REPORTS

A number of miscellaneous reports are required from all hydrographic survey parties in addition to any previously described in this chapter. Most of these are required at certain time intervals during the survey, or at the end of the season on an area basis. A description of each report, or form, required and the data to be furnished are given. A list of these is given in **859**; it should be referred to in conjunction with the list in **8351**.

### 851. Progress Sketches and Reports

Monthly, season's, and annual progress sketches and reports of all work accomplished, shall be submitted by field parties in accordance with the Regulations. In certain circumstances a semiannual progress sketch and report are required. Each of these shall be submitted as soon as practicable after the end of the period for which the report is made. All progress sketches shall be made on tracing cloth, using black ink only. Figure 185 shows the standard symbols to be used on progress sketches.

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### *8511. Monthly Progress Sketch*

The monthly progress sketch shall be submitted as soon as practicable after the end of each month. It should be made on tracing cloth with black ink only. The sketch and title should be neat and legible but expert penmanship is not required; mechanical lettering sets should be used.

The scale of the progress sketch is usually stated in the project instructions (see **1218**); otherwise it shall be that of the published chart covering the entire area of the season's work. Progress sketches of coastal surveys in the Philippine Islands should, if practicable, be on a scale of 1:100,000 (the scale of Philippine coast charts); for harbor surveys a larger scale may be used, if necessary, to show the triangulation clearly. The size of a progress sketch, in inches, should be no larger than is required to include the season's work, regardless of the size of the chart.

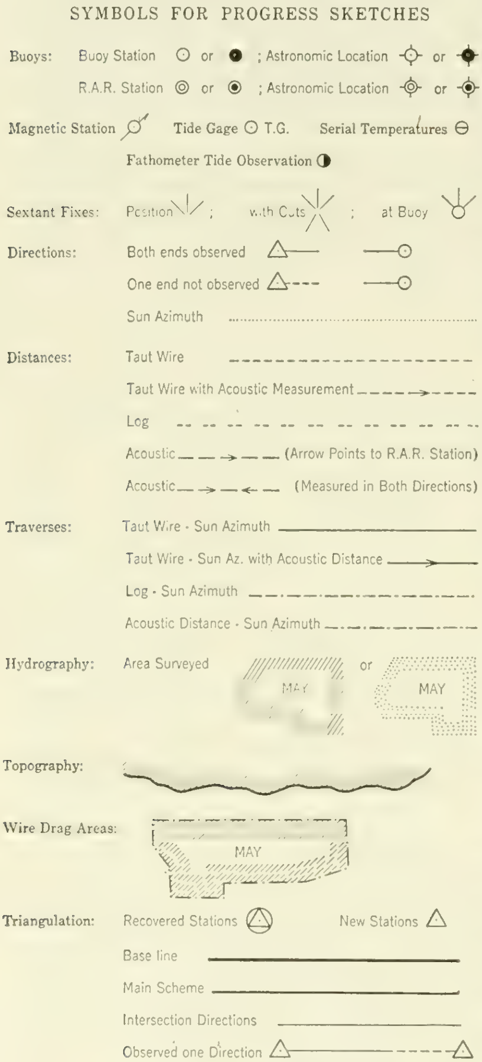


FIGURE 185.—Symbols for progress sketches.

Each progress sketch shall contain a title, similar to those on smooth sheets, giving the following information: class of work, locality, scale, project number, dates of survey, name of vessel or party, and name of Chief of Party. The scale may be given as a ratio, or by referring to the chart from which the projection has been traced.

The progress sketch must contain a projection and just enough shoreline and geographic names for easy identification; detail should be omitted so that all field work accomplished can be clearly shown.

Progress for all types of work should be added each month. The information should be generalized, the principal object being to report areas surveyed and in a way so that the information can be transferred to the Office progress charts; actual sounding lines should not be shown.

As the survey sheets are laid out (see **1361**), their limits should be shown and identified by field numbers on the monthly progress sketch, if this is practicable without confusion; otherwise the sheet layout diagram on a separate tracing should be forwarded to the Washington Office with the progress sketch each time additional sheets are laid out. (See also **1542**.)

A new monthly progress sketch shall be started at the beginning of each season, and continued throughout the season, irrespective of fiscal years. The results of each month's work are added from month to month. Monthly progress sketches will be

returned to the Chief of Party, without request, after the information on them has been transferred to the Office progress charts.

### *8512. Season's Progress Sketch*

A progress sketch, made on tracing cloth, summing all the information shown on the monthly progress sketches, shall accompany the season's report. The monthly progress sketch may be used for this purpose, if desired. The title must state "Progress Sketch to Accompany Season's Report," and should include the date of closing field work in addition to the information in the title of the monthly progress sketch. When this tracing is forwarded it should be accompanied by a request for the number of copies desired.

Any triangulation executed by a field party shall be shown on a separate progress sketch also attached to the season's report. This sketch should be prepared in accordance with instructions on pages 115 and 116 of Special Publication No. 145.

### *8513. Annual and Semiannual Progress Sketches*

A progress sketch on tracing cloth with maximum dimensions of 8 by 10½ inches (standard letter paper size) shall accompany the annual report and be submitted as of June 30 of every year. A similar progress sketch shall also accompany the semiannual report when the latter is required (see **8516**). If a field party has worked on more than one project during the fiscal year, a separate sketch is required for each. The scale of this sketch must necessarily be small. Triangulation may be generalized to show the area covered. The title should state "Progress Sketch to Accompany Annual Report" or "Semiannual Report," as the case may be, and include the following information: class of work, locality, project number, fiscal year, inclusive dates of field work, name of vessel or party, and name of Chief of Party.

### *8514. Monthly Progress Reports*

Each Chief of Party, each Commanding Officer, each District Supervisor, and each person in charge of a Processing Office or other independent establishment, shall mail to the Washington Office a brief monthly report of work accomplished. This report must be mailed so that it will arrive in Washington, D. C., not later than the 25th day of the month, and shall cover the period from the date of the previous month's report.

Each Chief of Party shall mail to the Washington Office, not later than the 10th day of each month, a report and daily journal of occupation of his party during the preceding month. This shall be made on Form 20*a*, Monthly Report and Journal of Field Party. It must be submitted in accordance with instructions printed on the back of the form; all pertinent details shall be furnished. This report, if properly kept, will furnish the information for computing the cost data required in **8515**(*f*).

Each Chief of Party, each Commanding Officer, and each person in charge of a Processing Office shall report monthly to the Washington Office the progress of office work on survey sheets and field records for which field work has been completed. These reports shall be mailed on the 1st day of the month. Separate reports are required for each project of each field party. Hydrographic surveys, topographic surveys, and other field records shall be reported separately on the three different forms which are provided, in accordance with the instructions at the bottom of each form.

Duplicate copies of reports from Processing Offices shall be mailed to the Chiefs of Party of the respective projects (see **926*b***).

The Forms to be used are:

*M*–961, Progress of Office Work on Topographic Sheets.
*M*–962, Progress of Office Work on Smooth Hydrographic Sheets.
*M*–963, Progress of Office Work on Field Records.

### *8515. Season's Report*

A season's report shall be submitted by every Chief of Party, not later than 1 month after the season's field work is completed. This report shall be in detail, covering each project completed or in progress. When field work on one project is continuous from July 1 to December 31, the report shall be made as of the latter date if there is no immediate prospect of completing the project. Descriptions of, and recommendations on, new methods of field work, descriptions of new instruments and equipment, and similar subject matter should be submitted as separate special reports (see **858**).

The following information and data should be included in the season's report:

(*a*) The project number and the name of the officer submitting the report at the top of the outside cover.

(*b*) Dates of original and supplemental instructions and of beginning and ending field work.

(*c*) A brief chronology of the activities of the party.

(*d*) Brief mention of any unusual activities, such as assistance rendered to other vessels or persons, and surveying that is not a part of the project (see for example **356**).

(*e*) The general organization of the party, including a list of all officers and the general capacity in which each was employed, giving any dates of reporting or detachment.

(*f*) A table of statistics on Form 21, Statistics, Cost, and Summary of Field Work, showing a summary of the results obtained. Where the report covers operations in 2 fiscal years the statistics for the 2 years should be separated. Instructions for the use of Form 21 are printed on its back.

(*g*) Cost data on Form 615, in accordance with instructions on the back of the form. The Monthly Report and Journal of Field Party, Form 20*a*, should be kept in such a manner that the information needed to compute the cost data will be readily available (see also **156**).

(*h*) A brief summary of the methods employed in executing the work.

(*i*) An inventory of all computations, field records, hydrographic and topographic surveys, either completed or uncompleted, including any already forwarded to the Washington Office or to a Processing Office, and any remaining on hand from previous seasons. There should be included an estimate of the time necessary to complete the office work on each sheet forwarded to the Washington Office or to a Processing Office for completion.

(*j*) The season's progress sketch in accordance with **8512**.

(*k*) A separate progress sketch on a larger scale, if necessary, showing only the triangulation.

### *8516. Annual and Semiannual Reports*

An annual report shall be submitted as of June 30 of each year on Form *M*-1133-5, Annual Statistical Report. This report must not be delayed—no other work shall be allowed to interfere with its preparation and transmittal. Statistics only are required, the information being needed for inclusion in the Director's annual report. A separate report must be made for each project. The person who is Chief of Party on June 30 shall submit this report for the entire fiscal year, regardless of the length of time he has been chief of that party. The annual progress sketch (see **8513**) shall accompany this report.

If a project is completed between July 1 and December 31, a semiannual report, similar to the annual report in all respects, shall be submitted as of the latter date; if

one project is in continuous progress and not completed on December 31, the semi-annual report is not required.

### 852. Navigational Information

All persons in the service of the Coast and Geodetic Survey should report to the Washington Office all valuable information obtained affecting the interests of navigation along the coasts. Special reports should be made promptly of any information of the following classes (giving in each case the authority and such recommendations as may seem desirable): rocks, reefs, shoals, or sunken wrecks (with the least depths on them), either not charted or incorrectly charted; important errors or omissions on the charts or in Coast Pilots; changes in depths or directions of channels; and changes in coastline, currents, etc. (See also section **17**.)

#### *8521. Chart Letters*

Miscellaneous information submitted by a field party and others for use in charting is filed in a "Chart Letter File" in the Nautical Chart Branch, and each communication is known as a *chart letter* and is given a consecutive number within the calendar year. Practically every communication of this kind is so filed.

Persons submitting such information should bear in mind the ultimate use of the data and submit them in a form convenient for this purpose. Letters should not be accompanied by enclosures of awkward size on which information has been noted in a way which prevents the enclosure from being cut into letter-size sections. Sketches should be on letter-size paper or be folded to this size; sections of charts, likewise, should be cut to letter size and if more than one chart-section is required to cover the area, the cutting should be done before any notations or other data are entered on them, to ensure that the entire notation appears on the section to which it refers.

#### *8522. Dangers to Navigation*

All dangers and wrecks discovered that are considered to be menaces to navigation shall be reported immediately by radio, telephone, or telegraph to the Commander of the nearest United States Coast Guard District and to the District Supervisor, and a copy of the notifying message shall be forwarded to the Washington Office. The message shall be in the following form: "(*object*) covered by (*depth of water*) at (*datum*) discovered; distant ------ nautical miles *or yards*, bearing ------ degrees true, from (*charted object*)."

A tracing from the boat sheet or chart showing the exact location of the danger discovered should be forwarded to the Washington Office at the earliest opportunity. A statement shall be included in the Descriptive Report mentioning each danger reported to the Coast Guard, so that such information will not be duplicated.

Floating wreckage, logs, derelicts, or other floating objects sighted which are menaces to navigation shall be promptly reported by radio, telephone, or telegraph to the Commander of the nearest Coast Guard District and a copy of this notification shall be forwarded to the Washington Office (see **365**).

#### *8523. Erroneous Charted Data*

Charts of the most recent print date and Coast Pilots of the area being surveyed should be examined carefully by the Chief of Party. Should any information of im-

portance be shown erroneously or inadequately the Washington Office should be notified at the earliest opportunity. (See also **173** and **175**.) In general, officers of the Coast and Geodetic Survey should carefully examine all charts and Coast Pilots covering areas with which they are familiar, and report any erroneous or inadequate information.

### *8524. Positions of Survey Buoys*

Each time survey buoys are established or removed a report shall be made at once to the Washington Office in order that this information may be published in the Notice to Mariners (see **286**). The report should give the positions of the buoys and should state the type and whether lighted or not, and if lighted the color and characteristics of the light. Where the buoys are equally spaced in a line, it is sufficient to report the latitudes and longitudes of the two buoys at the ends of the line and the number of intermediate buoys; otherwise the latitude and longitude of each should be given.

## 853. Aids to Navigation

Aids to navigation are established to aid the mariner in navigating the adjacent waters and it is vitally important that the aids be correctly charted, that the floating aids be maintained in their charted positions, that they be correctly placed with reference to the new survey, and that any deficiencies be promptly reported.

Where the actual description or characteristics of any aid to navigation are found to differ from those published in the Light Lists or on the charts, the facts shall be reported immediately to the Commander of the nearest United States Coast Guard District and to the Washington Office.

Where a lighted aid to navigation is found extinguished, report should be made immediately to the Commander of the nearest Coast Guard District (see also **174**).

Reference shall be made in the Descriptive Report to every report, made during the course of the field work, to Coast Guard officials relative to aids to navigation (see **842*P***).

### *8531. Positions of Floating Aids*

All floating aids to navigation within the area of a survey shall be located, and listed in the Descriptive Report for that survey. The latitude and longitude of each, the depth of water at each, the position number or numbers of the location data, and the date of location shall be given. (See **842*P***.)

The charted position of a floating aid to navigation is its official position, until notice of a change is published in the Notice to Mariners, in which case the charted position is corrected by hand, pending a corrected printing. Every effort is made by the Coast Guard to maintain floating aids at their official positions.

Errors in the positions of floating aids are of two classes, (*a*) when the aid is not at its official position and (*b*) where the official position of the aid does not adequately serve the purpose for which it was intended.

During the survey, if the official position of a floating aid is adequate for the purpose intended, but the aid is found to be not at its position, the latter fact shall be promptly reported directly to the Commander of the nearest Coast Guard District. It is important to report the date on which the aid was found to be off station and the distance and direction it was off station.

During the survey, where the official position of a floating aid is found to be unfavorably located for the purpose for which it was intended, the facts shall be reported

to the Commander of the nearest Coast Guard District and to the Washington Office in writing. The report should be accompanied by a photostat or tracing of the applicable part of the new survey as shown on the boat sheet, with a recommendation as to where the aid should be located. (See also **3832**.)

Where the survey discloses the need for additional aids to navigation to mark newly discovered dangers, recommendation shall be made promptly to the Commander of the nearest Coast Guard District, and a copy of the recommendation shall be forwarded to the Washington Office.

Where the survey discloses the need for additional aids to navigation to mark channels, or for any reason other than that given in the preceding paragraph, the recommendation shall be forwarded to the Washington Office accompanied by a photostat or tracing of the applicable part of the boat sheet.

### *8532. Positions of Fixed Aids*

The geographic positions of *all* fixed aids to navigation which were *located* during the season should be reported on Form 567, Landmarks for Charts. In making out this form, the applicable parts of the instructions given in **8534** should be followed. It is important that the names of the aids entered on the form be identical with those in the Light Lists.

It is to be emphasized that the positions of all aids located are to be reported, even if the new positions merely serve to verify previous geographic positions, or the charted positions.

The report shall be made on an area or seasonal basis. A separate report for each hydrographic sheet is not desired. The aids to navigation shall be listed separately from the landmarks, since these reports serve a different purpose in the Office. (See also **3831**.)

Azimuths of ranges determined in accordance with **3833** shall be reported in the Descriptive Report for each survey (see **842*P***).

### *8533. Chart of Objects for Use of United States Coast Guard*

The objects selected for the use of the United States Coast Guard in accordance with **1551**, shall be plotted on a copy of the latest print of the largest-scale chart of the area. The chart should not be cut into sections, even though the notes apply to only a part of the area of the chart. A short legend as, "Objects for Use of U. S. Coast Guard," and the date of the field survey from which the information was obtained, shall be shown on this chart.

The three objects selected for each fix shall be encircled in red on the chart, whether already charted as landmarks or plotted by the survey party. Adjacent to the position of each object selected, a description from which the object may be identified shall be noted in red. The fix selected for each aid shall be indicated on the chart by red arrows at the aid, pointing toward the objects to be used.

Charts with the legend "N.A. 1927" printed in the upper right-hand corner are on the North American datum of 1927. Charts for continental United States without legend in the upper right-hand corner, may be on either the North American datum of 1927 or the North American datum (see **1125** and **2171**). The geographic datum of a chart may be ascertained by comparing the scaled position of a charted object with its geographic position as given in the triangulation data (see **7362**); or the datum will be

furnished by the Washington Office on request, as will the difference in meters between the field datum and the chart datum.

The prepared chart, after the information placed thereon has been carefully verified, shall be forwarded by the Chief of Party directly to the Commander of the Coast Guard District in which the area is located, with a transmitting letter stating its purpose. There may be included in this letter any explanatory information needed in interpreting the data contained on the chart, although the data furnished on the chart should be complete, if practicable.

The following data shall be forwarded to the Washington Office:

(*a*) A copy of the transmitting letter.

(*b*) A list of the objects, with their latitudes and longitudes, that have been plotted on the chart forwarded to the Coast Guard. The list shall be prepared on Form 567, Landmarks for Charts, and should include only those objects not already charted. To avoid confusion with the regular use of the form, the title should be cut off and a new heading, "Objects for Use of U. S. Coast Guard," written in. The datum used shall be stated.

(*c*) A special report of this work.

The transmittal of these data shall be handled as a separate subject. No other field information or notes shall be attached to the forwarding letter, or included in the envelope.

### *8534. Landmarks for Charts*

A report on landmarks for charts, in duplicate, on Form 567, Landmarks for Charts, is required for all hydrographic surveys. This report shall be submitted at the end of the season for the project as a whole and not for each hydrographic or topographic sheet. The original copy of Form 567, together with any accompanying charts or sketches submitted, is numbered and filed as a Chart Letter in the Division of Charts (see **8521**). For this reason any sketches submitted shall be of letter size or prepared for folding to that size; likewise, any charts submitted shall be cut into letter-size sections. The duplicate copy should be marked "Coast Pilot Section" and notations made on it as to the relative prominence of each landmark, the directions from which each is visible or obscured, and how the landmarks affect the Coast Pilot. Only one copy need be submitted of any chart-sections or sketches.

Reports on landmarks shall, if possible, be complete in themselves in order that further reference to triangulation data and topographic sheets may be avoided. The report shall state whether or not an inspection has been made to determine the value of the landmarks when viewed from the water area.

Landmarks no longer in existence or which should be deleted from the chart for any other reason, shall be reported as follows:

(*a*) Where only a few landmarks are to be reported, Form 567 may be used. The geographic positions need be given to the nearest tenth of a minute only. List these on a separate copy of the form and not with new landmarks to be charted.

(*b*) Where a number of landmarks are to be reported, chart-sections shall be submitted on which the landmarks to be deleted are indicated (see B(3) below). Form 567 need not be submitted. Forward these chart-sections by a transmitting letter, a copy of which shall accompany other reports on Form 567 submitted at that time.

Flagstaffs and flagpoles, because of their temporary nature, should be listed as landmarks only where there are no other suitable objects in the vicinity or if they are of a very permanent nature.

### A. PREPARATION OF FORM

Form 567 shall be prepared in accordance with the following instructions:

(1) Objects of special importance or prominence shall be indicated by an asterisk (*) preceding the name of the object. In the selection of these, the total area involved should be considered by localities. Where an object is the most prominent in a locality it should be so marked, even though it may be less prominent than many others in an entirely different one. This is desirable in order that a proper distribution of landmarks may be available rather than a concentration of them in one locality.

(2) In the first column headed "Description" the description shall be divided into three parts, as follows:

(*a*) The name recommended for charting shall be in capital letters. It should be short and a general term and usually should not be accompanied by any descriptive terms.

(*b*) Descriptive terms shall follow in lower-case letters. If it is essential that any descriptive term be charted in addition to the name, then the descriptive term shall also be in capital letters.

(*c*) Any other identifying data shall be in parentheses. If the landmark has been located by triangulation, or used as a hydrographic signal, the name of the triangulation station or the hydrographic signal shall be given in parentheses. This will identify the landmark in the other records. In general such identifying data shall never be used in charting.

(3) In the columns headed "Position" the position, where accurately known, shall be given in degrees, minutes, and the *dms.* and *dps.* in meters, and where so given the data will be assumed to be sufficiently accurate for all charting purposes. If the position is *not* known accurately enough for charting purposes, the data shall be given in degrees, minutes, and tenths of minutes; and where so given they will not be used for charting until more accurate data have been obtained. The method of location and the datum used shall always be entered.

(4) After Form 567 has been prepared and typed, the positions as given on the typed copy shall be verified by plotting them back onto the original survey sheets or, in the case of triangulation stations not on any sheet, by comparing them with the original checked computations; and a signed statement that this has been done shall be made on the copy submitted. Checkmarks shall be shown on the form after the *dms.* and *dps.*

### B. PREPARATION OF CHART-SECTIONS

Where a number of landmarks are reported, a recently printed copy of the chart of the area, cut into letter-size sections, shall be prepared and submitted, in addition to Form 567. The area which has been inspected shall be outlined on these chart-sections, and a recommendation shall be made for each charted or plotted landmark within the area outlined. The following procedure shall be used:

(1) New landmarks shall be plotted and identified by the landmark symbol (⊙) accompanied by the name recommended for the chart. The geographic datum of the chart must be known and considered in the plotting (see **8533**).

(2) Charted landmarks, the continuance of which is recommended, shall be checkmarked (✓), and where the position has been actually verified during field work, the checkmark shall be accompanied by the word "verified." Where a landmark has been verified only by visual inspection, the word "verified" shall be omitted.

(3) Charted landmarks, the deletion of which is recommended, shall be indicated by an X in a circle, accompanied by the word "delete" (⊗ delete), and the reason for the recommendation shall be given.

If chart-sections are submitted, landmarks to be deleted need not be listed on Form 567.

Where new uncharted landmarks are shown on the chart submitted, a notation shall be made thereon in a prominent place giving the latitude and longitude, with seconds in meters, of some one charted landmark, as is required in paragraph 34, page 8 of the Topographic Manual. The datum used shall also be noted on the chart.

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Names and notations on these chart-sections shall be typed or lettered legibly in red ink. Care must be taken that such notations always appear on the same section as the landmark to which they refer.

### C. STANDARDIZATION OF NOMENCLATURE

It is essential for charting purposes that the nomenclature used, and the method of reporting it, be standardized. The cartographers should not have to interpret these data because they cannot see the object in the field and cannot know what is most prominent about the landmark. If a landmark is reported on Form 567 as a "Tall yellow tank," the cartographer cannot tell whether the landmark is prominent because it is a tank, because it is yellow, or because it is tall. The field party must interpret these data and give them in proper form for charting. The following standardization of nomenclature must be considered general but is to be followed so far as practicable.

In general, descriptive terms shall be omitted from the name recommended for the chart. Colors describing an object are particularly objectionable on account of their temporary nature. The material out of which an object is built is not valuable on the chart, since the mariner even where only a short distance away cannot identify an object by the material. The adjectives tall and tallest are unnecessary, because if the object were not tall it would not be a prominent landmark. Where a descriptive term is necessary to distinguish a charted landmark from other landmarks in the vicinity which are not charted or not located, then the descriptive term shall be in capital letters according to A(2)(*b*) above.

In general the use to which an object is put is nonessential on the chart, unless this use contributes to the identification of the object. In reporting buildings as landmarks, avoid so far as possible using a name that indicates the use to which the building is put. It is preferable to use some term such as DOME, TOWER, or SPIRE, which describes the shape of the top of the building. The name describing the use, such as schoolhouse or courthouse, shall follow in lower-case letters.

In general the company's name shall be omitted from the chart unless this name or an abbreviation of it is visible on the landmark in letters large enough to serve as an identifying feature to the mariner. The company's name should properly come under A(2)(*c*) above.

In a few cases of very well-known buildings, the name of the building shall be charted in parentheses following the name of the landmark, as DOME (STATE HOUSE), TOWER (EMPIRE STATE BLDG.).

Where two similar objects are closely adjacent the word "twin" shall be omitted if the objects are charted as two separate landmarks. Where they are indicated as only one landmark the word "twin" shall be used.

In cases where only one of a group is to be charted, the name should be followed in parentheses by a descriptive legend, including the number in the group, as for example (TALLEST OF FOUR) or (NORTHEAST OF THREE).

In the name or description of a landmark, its relation to other topographic features is unessential since this is shown graphically on the chart.

Abbreviations of colors, where given, shall be in accordance with the standard bottom characteristic abbreviations (see part "S" of the Symbols and Abbreviations chart, fig. 189).

The following classifications, which include most landmarks, are defined and accompanied by remarks to standardize their use. They shall be so used so far as practicable.

BUILDING.—(See House.)

CHIMNEY.—That projecting part of a building for conveying smoke, etc., to the outer air. This term is to be used only where the building is the prominent feature and the charting of some specific part of it is desirable; for example, the chimney of a large factory.

CUPOLA.—A small turret or dome-shaped tower rising from a building, in cases where the building is the prominent object and where the cupola is small as compared to the building.

DOME.—A large cupola of rounded hemispherical form, or a roof of the same shape, whether it is actually rounded or many-sided.

FLAGPOLE.—A single staff flagpole rising from the ground and not attached to a building.

FLAGSTAFF.—A single staff flagpole rising from a building. This is not desirable as a landmark, due to its nonpermanence. Although it is desirable that the most definite part of a building (such as the flagstaff) be pointed at in making observations, this is not necessarily the most important part for charting purposes. Wherever possible give, for use on the chart, that part of the building from which the flagstaff rises, as TOWER, CUPOLA, DOME, etc.

FLAG TOWER.—Any scaffold-like tower on which flags are hoisted, such as a Coast Guard skeleton steel flagpole or a Weather Bureau signal tower. Do *not* use *Signal Tower.*

GAS TANK or OIL TANK.—Since these differ in shape and size from a water tank, the compound name will be used.

HOUSE or BUILDING.—Although it is desirable to locate a house or building by observations on a specific point, as the west gable or the flagstaff, such terms are not desirable for charting purposes, where it is the structure itself which is the landmark. Use HOUSE or BUILDING followed by a description of the point in either capitals or lower-case letters, according to whether it should be used on the chart or not. Where the outline of the building should be shown on the chart, the following notation—"chart outline"—should be made on Form 567.

LOOKOUT TOWER—Any tower surmounted by a small house in which a watch is habitually kept, such as a Coast Guard lookout tower or a fire lookout tower. Do *not* use this term in describing an observation tower, or a part of a building in which no watch is kept.

MONUMENT.—Do *not* use *Obelisk* or other terms.

OIL TANK.—(See Gas Tank.)

RADIO MAST.—A general term to include any tower, pole, or structure for elevating antennas.

SPIRE.—In general, any slender pointed structure surmounting a building. The spire is rarely less than two-thirds of the entire height and its lines are rarely broken by stages or other features. Do *not* use *Steeple.* Spire is not applicable to a short pyramid-shaped structure rising from a tower or belfry.

STACK—Any tall smokestack or chimney, regardless of color, shape, or material, if the stack is more prominent, as a landmark, than any buildings in connection with it. Do *not* use *Chimney.*

STANDPIPE.—A tall cylindrical structure, in a waterworks system, whose height is several times greater than its diameter.

TANK.—A tank for holding water, when its base rests on the ground or other foundation, and its height is not much greater than its diameter.

TANK (ELEVATED).—A tank for holding water, where such tank is elevated high above the ground or other foundation by a tall skeleton framework.

TOWER.—(*a*) A part of a structure higher than the rest, but having vertical sides for the greater part of its height.

(*b*) An isolated structure with vertical sides (not otherwise classified), high in proportion to the size of its base, and of simple form.

(*c*) The top of a skyscraper, high in proportion to its horizontal size and rising above its surroundings.

(*d*) Any structure, whether its sides are vertical or not, with base on the ground and high in proportion to its base. Its sides may be open framework, such as a Bilby steel tower.

TREE.—Do *not* use *Lone tree* or *Conspicuous lone tree.* This is assumed, otherwise the tree would not serve as a landmark.

WATER TOWER (infrequent).—A decorative structure enclosing a tank or standpipe, or used as such, when by its appearance it would not be recognized as such.

WINDMILL.—A self-explanatory term.

## EXAMPLES

CHIMNEY, schoolhouse (Mt. Vernon H. S.)
CUPOLA, schoolhouse (Normal School, 98 ft. high)
FLAGPOLE (Green Hill Country Club)
LOOKOUT TOWER, fire, steel (110 ft. high)
SPIRE, church (△ Nanticoke Church Spire)
STACK (Aiea Mill)
STACK, black, metal (at Hot House)
STACK (TALLEST OF FOUR), black
STACK, white, concrete
TANK (BAY STATE CO) (⊙ Bay)
TANK (SOUTH) (southerly of three yellow tanks)
*TANK, steel (125 ft. high)
TANK, yellow (△ Hot)
*TOWER (CITY HALL)

### 854. Descriptions of Stations

Station descriptions on the appropriate forms shall be submitted for all triangulation stations, and all recoverable topographic and hydrographic stations. The descriptions for the triangulation stations should be submitted for the entire project or season and should be forwarded by transmitting letter with other triangulation records and *not* included on a transmitting letter with other records pertaining to hydrography. The descriptions of recoverable topographic and hydrographic stations should be submitted for each sheet with the other records having to do with that survey. (See also **2142**.)

A description should be typewritten and only one side of the form used; if additional space is required, one or more continuation cards should be used.

The correct form to use in each case, with a reference to the text where the proper use of each form is described, is listed below:

| | Form No. | Reference |
|---|---|---|
| Triangulation station established | 525 | **227** |
| Triangulation station recovered, lost, or searched for but not found | 526 | **2272** |
| Stations of other agencies connected to C. & G. S. triangulation | 525 | **2271** |
| Recoverable topographic station established | 524 | **2351** |
| Recoverable topographic station recovered, lost, or searched for but not found | 524 | **2351** |
| Stations of other agencies located by C. & G. S. topography | 524 | **236** |
| Hydrographic stations (see topographic stations) | 524 | **245** |

### 855. Coast Pilot Report

Coast pilot notes should be forwarded in duplicate as a separate report at the end of the season. While such notes are used in the compilation of new editions, they are usually published first in Supplements. The report should therefore be submitted in such form that one copy of it can be cut and used in the Coast Pilot Section without copying. Instructions for the preparation of coast pilot notes are given in **9121** and **915**.

During a hydrographic survey each hydrographer should keep a journal in which notes and memoranda are entered for use in compiling the general coast pilot report at the end of the season (see **159** and **385**). These notes should include information obtained while en route to and from the project area as well as that resulting from the season's field operations (see **175**). Any information reported under "*O*, Coast pilot information," in the Descriptive Report (see **842*O***) should be repeated in the coast pilot notes, or an extra copy of that part of the Descriptive Report should be mailed

separately and marked for the attention of the Coast Pilot Section. Important information should be forwarded at once, but the general report should be submitted at the end of the season. In all cases where information in the Pilots is found to be accurate and adequate a statement to this effect should be included in the notes.

Coast Pilot notes should be complete, clear, and accurate. Any sailing directions should be checked before inclusion in the report.

### 856. Geographic Name Report

Where practicable, a special report on geographic names shall be submitted to cover the project area, or that part of it surveyed during the season. Where only one hydrographic sheet comprises the project, the information may be included in the Descriptive Report (see **842*R***). The information to be included in the report is described in detail in **163**, and other information of value in composing the report is contained in section **16**.

In case the project area has recently been covered by air photographic surveys and a geographic name report has been submitted in connection with that project, duplication is to be avoided. Only new information which is disclosed and names in the water area which were not investigated by the air photographic party should be included.

### 857. Ranges for Compass Deviations

In addition to showing on the smooth sheet, in accordance with **7845**, all useful ranges of natural objects and those established by the United States Coast Guard, a special report should be made for each project or season's work, of prominent and easily distinguished objects and ranges that are suitable for use in determining deviations of ship magnetic compasses and errors of gyrocompasses.

The report should include a description of each object, its latitude and longitude, and its intended use; special emphasis should be placed on how to identify it with certainty from the area where it will probably be observed; the azimuths of all recommended ranges should be included, with a statement as to how each was determined. Instructions for obtaining azimuths of ranges by planetable and sextant are contained in **3833**.

Mention should be made in this report if any azimuths from wharves were determined in accordance with **356**, and to whom the results were given.

### 858. Special Reports

Special reports on other subjects, which are of broad scope or interest and which are not restricted to the survey or the season's work, should be submitted from time to time. Each of these should be written as an entity and under no circumstances should such information be included in either the season's report or a Descriptive Report. Each of these reports should be entitled "Special Report on (*subject matter*) by (*author's name*)." It should be approved and forwarded by the Chief of Party. Among the many subjects which should be treated in this manner a few are specifically mentioned.

#### *8581. New Methods and Equipment*

All members of survey parties should be encouraged to study the principles involved in hydrographic surveying and to experiment with new methods and apparatus. Descriptions of new methods and apparatus, and suggestions for the improvement of those in use should be furnished as separate reports.

Changes in methods and equipment that will have no effect on the accuracy of operations, such as the design of a new type of signal or buoy, may be used without prior approval of the Washington Office. Those changes which do affect the quality of the work, such as new instruments, etc., may not be used in actual survey work until approved by the Office.

### *8582. Submarine Features of Interest*

Modern methods of surveying are disclosing in considerable detail submarine features of interest to scientists and geomorphologists, as well as to navigators. Most prominent among these are the large submarine valleys and canyons indenting the continental shelves and slopes, and the large submarine mountains. There are many other submarine features of less spectacular size, such as silted areas and sand waves, which the survey may disclose that may be of as great or greater interest. Special reports on such features are particularly valuable.

### *8583. Photographs*

Photographs of field activities, personnel, and equipment, particularly those that illustrate actual survey operations, are of considerable value, and no opportunity to obtain them should be neglected.

Negatives are preferable to prints. Personal negatives may be forwarded to be copied and returned to the owner.

Negatives or prints should be submitted separately and not made a part of a special or season's report. Each photograph should be accompanied by Form 623*A*, Photograph History. (See also **1591**.)

### *8584. Weather*

Weather is a major factor in the quantity and sometimes in the quality of hydrographic surveying. Where a party is operating in a remote region, about which there is comparatively little of record concerning the weather, the experience of the party should be furnished in the form of a special report, which may be of aid to others working in the same locality. Likewise, similar reports should be furnished for seasons when abnormal weather conditions are encountered in comparatively well-known areas. (See also **1453**.)

### *8585. Scientific Knowledge*

Officers surveying in remote regions should be alert to their opportunities to contribute valuable information to other branches of science, such as geology, anthropology, volcanology, and glaciology, among others. Such information should always be furnished in a special report.

## 859. Reports Required From Hydrographic Parties

For convenience a list of the miscellaneous reports required at various times from the hydrographic parties is furnished below, with the form numbers, if any, and references to the places in this Manual where the requirement is mentioned. (See also **8351**.)

ANNUAL

| *Name of Report* | *Form No.* | *Reference number* |
|---|---|---|
| Progress sketch | Tracing cloth | **8513.** |
| Statistical report | *M*–1133–5 | **8516** and **156.** |

## SEMIANNUAL

[Required in certain circumstances.]

| *Name of Report* | *Form No.* | *Reference number* |
|---|---|---|
| Progress sketch | Tracing cloth | **8513.** |
| Statistical report | *M*–1133–5 | **8516** and **156.** |

## MONTHLY

| | | |
|---|---|---|
| Progress of office work on sheets and records | *M*–961, *M*–962, *M*–963 | **8514.** |
| Progress sketch | Tracing cloth | **8511.** |
| Sheet layout | Tracing cloth | **8511.** |
| Report and journal | 20*a* | **8514** and **156.** |
| Report of progress of field work | Letter to arrive at Washington Office by the 25th of each month. | **8514.** |

## BEGINNING OF SEASON

| | | |
|---|---|---|
| Acknowledgment of project instructions | Letter | **121.** |

## END OF SEASON

| | | |
|---|---|---|
| Chart of objects for use of U. S. Coast Guard | 567 and chart | **8533** and **1551.** |
| Coast pilot report | Letter | **855**, **159**, and **385.** |
| Descriptions and recovery notes of triangulation stations | 525 and 526 | **854.** |
| Geographic name report | Written | **856** and **163.** |
| Landmarks for charts, in duplicate, duplicate copy marked "For Coast Pilot" | 567 and chart-sections | **8534** and **155.** |
| Positions of fixed aids to navigation | 567 | **8532** and **3831.** |
| Ranges for compass deviations | Letter | **857.** |
| Report of buoy locations | Written | **8322**, **8323**, and **8324.** |
| Season's report—and the following attached: | Written | **8515.** |
| Cost data | 615 | **8515** and **156.** |
| Index of sheets (optional) | Tracing cloth | **8413.** |
| Inventory of records | In season's report | **8515.** |
| Progress sketch | Tracing cloth | **8512.** |
| Separate progress sketch of triangulation only | Tracing cloth | **8512.** |
| Statistics | 21 | **8515** and **156.** |
| Velocity of sound report | Written | **833.** |
| Abstract of temperatures, salinities, and theoretical velocities of sound | 717 | **833.** |

## AT VARIOUS TIMES

| | | |
|---|---|---|
| Chart letters | Letter or chart-section | **8521.** |
| Dangers to navigation, immediate report | Letter or radio | **8522.** |
| Field examinations | Tracing or chart-section | **176.** |
| Floating aids to navigation off station or poorly situated | Letter | **8531** and **3832.** |
| Information erroneously or inadequately charted | Letter | **8523** and **173.** |
| Lighted aids extinguished | Radio | **853** and **174.** |
| New methods and equipment | Letter | **8581.** |
| Report of installation of tide gage | 681 | **1434.** |
| Sheet layout diagram (if separate) | Tracing | **8511** and **1542.** |
| Special reports on any phase or feature of work | Letter | **858.** |
| Survey buoys established or discontinued | Radio | **8524** and **286.** |

# CHAPTER 9. MISCELLANEOUS

## 91. COAST PILOT

The Coast Pilots of the Coast and Geodetic Survey are a series of volumes containing information of importance to the navigator which cannot be shown conveniently on charts and is not readily available elsewhere. The information covers a wide variety of subjects, among which are descriptions of the coasts, harbors, dangers, and landmarks; and directions for entering harbors and for coastwise navigation. A new edition of a Pilot is published about every 7 years, although the interval may vary from 5 to 12 years depending on the importance of the region, the number of changes, and other factors. Supplements, containing corrections, changes, and new information, are published about once a year.

### 911. SOURCES OF COAST PILOT INFORMATION

The information used in the preparation of Coast Pilots and Supplements comes from many sources, the most important of which are:

Files in the Coast Pilot Section, Washington Office.
Field revision parties.
Coast pilot reports from field parties.
Chart Letters and other files in the Nautical Chart Branch, Washington Office.
Survey sheets, Descriptive Reports, and files in the Map Hall, Washington Office.
Nautical publications by other federal bureaus; and by State, port, and local authorities.

### 912. COAST PILOT REPORTS FROM FIELD PARTIES

Coast pilot reports from field parties are among the most important sources of information. If properly prepared, they furnish a type of information, often unobtainable elsewhere, that is most needed, such as controlling depths; descriptions of coasts and landfalls; strength of currents; and existence of tide rips and cross currents. If such information is not included in the field party's report, an exhaustive and often time-consuming examination of Descriptive Reports and survey sheets is required, which does not always yield the best results.

A mere revision of the published text of a Pilot is not all that is required, but additional new information should be obtained that will enhance its value. This applies to a surveyed as well as an unsurveyed area.

Insofar as practicable, advantage should be taken of the transit of vessels between ports to check the applicable parts of the Coast Pilot. Errors and deficiencies should be reported (see **175**).

Information of local origin relative to the area in which a field party is working should be investigated and reported. Likewise, directions in an area being surveyed should be verified by actually running the courses and sounding along them before they are recommended and submitted to the Office (see **356**).

Information vital to the navigator should be reported at once and by radio, if necessary. General notes, in duplicate, should be submitted at the end of the field season, and should be clearly marked "Coast Pilot Report" (see **159** and **855**).

### *9121. Preparation of Report*

The manner in which the report is prepared is important. A new survey usually necessitates a number of corrections and changes in the Coast Pilot, and in such case the report should be prepared in the same manner as the Supplements are, giving references to the page and line numbers (see **915**). It is only necessary to supply the new data, and to indicate the page, paragraph, and line affected; this avoids recopying a considerable part of the text that does not require change.

Where the text of the Pilot is correct and adequate, the report should consist of a mere statement to that effect, with an exact reference to that part of the Pilot referred to. Where many short changes are to be made, as in names or depths, they should be shown in the margins of pages cut from the Pilot, with leaders or arrows indicating the parts affected. Where changes are extensive and include much new information, pages may be cut from a Pilot and bound together with sheets of blank paper. The changes and the new information can then be typed on the blank sheets and referenced to the printed text on the opposite page.

The report should be submitted in such form that one copy of it can be cut and used in the Coast Pilot Section without copying. The duplicate copy is filed until it is needed for revision or manuscript.

The person preparing a coast pilot report should be familiar with **916**, where the material desired for Coast Pilot is defined.

### *9122. Landmarks for Charts*

Form 567, Landmarks for Charts, should be submitted in duplicate. The duplicate copy should be marked, "Coast Pilot Section," and notations should be made on it to show the relative prominence of each landmark, the directions from which each is visible or obscured, and how the landmarks affect the Coast Pilot. (See **8534** and **916**, Landmarks.)

### *9123. Coast Pilot Copies of Correspondence*

When correspondence from the field includes information of value to the Coast Pilot Section, an additional copy should be forwarded, clearly marked "For Coast Pilot Section."

## 913. Preparation of a New Edition

The various steps necessary in preparing a new edition of a Coast Pilot are described in **9131** to **9139** inclusive.

### *9131. Preparation in Office for a Field Inspection*

After the decision has been made that a new edition of a Coast Pilot is required, it must first be determined what parts, if any, of the region described in the Pilot need to be field inspected by the reviser. This depends on the adequacy of the available information and on the character of the region. Such a decision must be made for each new edition prepared.

If a field inspection is required, all available information applying to the current edition of the Pilot must be examined, and the part that needs consideration or verification in the field assembled for entry in the Field Record Books. During the period of preparation for a field inspection, the reviser should thoroughly familiarize himself

with coast pilot requirements, and with the purposes of other nautical publications. He should avoid entering in the record a mass of information that will never be used, but which will have to be sorted over and only delays the writer of the manuscript.

*a. Field Record Books.*—These books are prepared for the convenience of the reviser and writer; they also constitute the permanent record which is retained in the files of the Coast Pilot Section for reference during the life of the edition. Large blank record books, about 10 by 14 inches in size, are most suitable for this purpose. Stock No. 50187 is satisfactory.

The printed pages are cut from two Coast Pilots and mounted on the left-hand pages of the record books. This leaves a wide margin on the left-hand page and the entire right-hand page for the entry of notes and corrections. It is advantageous to mount the text in separate paragraphs, with spaces between them. Then the information selected from the coast pilot files should be entered, with a reference to the authority in each case. Some of this can be pasted, and some written in ink, using ink of a different color from that to be used by the reviser in the field.

Each entry written in these record books should be referred to the exact place in the text of the Pilot to which it refers, by a leader or arrow, by corresponding numbers, or by some other unmistakable means. With a little care the reviser, at the end of his field work, will have a nearly complete rough manuscript, thereby reducing considerably the time required for preparing the manuscript for the printer.

In one of the record books a definite section should be set aside for the assembly of tables for the appendix of the Coast Pilot (see **9135B**(5)). As far as possible the tables should be prepared in the Office and checked in the field.

*b. Publications, instruments, etc.*—The following publications, instruments, and other material are required for a field inspection:

*Publications*

Charts of the area, corrected to date—two complete sets (three copies of some) will be needed.
Coast Pilot, extra copies.
Current Tables and other publications on currents, such as Current Charts.
Latest Coast Pilot Supplement, extra copies.
Light Lists.
Notices to Mariners (arrange to have them mailed to reviser in the field).
Pamphlets and maps from oil companies.
Privately published coast pilots.
Radio Navigational Aids, H. O. 205.
Radio Weather Aids to Navigation, H. O. 206.
Style Manual (Government Printing Office).
Tide Tables.
United States Corps of Engineers publications:
    Port Series.
    Port and Terminal Charges.
    List of Bridges over Navigable Waters. (Have a copy corrected to date for the region involved.)
    Annual Report.
    Rules and Regulations.

*Instruments*

Binoculars.
Boat compass.
Boxes for stationery, books, and instruments.
Brief case.
Chart cases.
Ditty box with pencils, dividers, erasers, ink, clips, rubber stamps, triangles, ruler, etc.
Drawing instruments.
Field desk.
Fountain pens.
Leadline.
Parallel rulers.
Planetable (see theodolite).
Prismatic compass.

Protractors, three-arm metal and celluloid.
Scales, metric.
Sextant.
Tapes, 300-foot and 30-meter.
Theodolite (not necessary unless some special field work is required).
Watch.

*For accounts, the following items are required*

All necessary stationery and forms for submitting monthly accounts, truck record, launch log, etc.
Approved estimates (obtain these before going into the field).
Contracts for supplies:
- Tires and tubes.
- Spark plugs.
- Batteries.
- Arrange for credit cards for the purchase of gasoline and oil.

Orders—allowance for mileage, etc.
Requisition of funds and checks.

*c. Local federal offices.*—Before beginning field work, the reviser should obtain as many addresses as possible of the local offices maintained by various federal agencies in the region to be inspected. These are published in the appendix of the Coast Pilot (see **9135**B(5)). Many of these offices are important sources of information.

*d. Transportation.*—The principal means of transportation to be used must be determined. This may be by boat or truck. There are advantages to both and the matter should be carefully weighed, with the particular region and the comparative expense in mind.

In some regions a boat is indispensable, and the best size is one large enough to include living quarters for the party. In other localities the principal traveling may be by truck, and local launches can then be used. In such cases, an attempt must be made to arrange for the temporary use of launches operated by the Bureau, or by some other government agency. If this is impracticable, private launches may be chartered as required. Ferry boats and local steamers can be used to advantage.

If possible, authority should be obtained from the Commandant, United States Coast Guard, for the reviser to travel on the vessels of that bureau. In some ports limited cooperation of this kind may be obtained from the United States Corps of Engineers, or from port authorities.

*e. Duplication of information.*—Several federal agencies publish information formerly found only in Coast Pilots. Some of these publications are kept current by daily or weekly corrections issued free of charge. Information thus available should not be repeated in the Coast Pilots except in special circumstances. In particular, information that is subject to frequent changes should be omitted; for example, light and fog-signal characteristics. If such information were included, it might be obsolete before the new edition of the Pilot is issued. Furthermore, it would be undesirable duplication, since details of such changes may be found in three other publications that are issued free of charge. Coast and Geodetic Survey charts also show these changes, being corrected by hand to the date of issue. Likewise with many other instances of duplication—and the reviser will save himself a great deal of needless work and have a much more legible Field Record Book if he keeps this constantly in mind.

*f. Extent of detail.*—Excessive detail must be avoided. The size and type of vessels using each particular waterway must be taken into account, as well as the amount of traffic. Usually the requirements, not only of the professional navigator, but of the yachtsman and fisherman as well, must be kept in mind. Allowance must

also be made for the thoroughness with which the region has been surveyed and charted. If the surveys of the area are incomplete, if the harbor charts are on too small a scale, or if a harbor has grown in importance, more detail will be required in the Coast Pilot. The amount of detail required in describing various features in new editions is given in **916**.

### *9132. Field Inspection for Coast Pilot Revision*

*a. Purpose.*—The principal purposes of a field revision are to verify and correct all statements in the Pilot, to delete material no longer of value, and to add new worthwhile information. In addition to this, local deficiencies in the charts and suggestions for their improvement should be obtained and reported to the Washington Office. Arrangements should be made for local correspondents to inform the Office of all future changes affecting navigation.

*b. Record.*—The reviser should enter in his Field Record Books all information to be used in revising the Pilot, with authorities where practicable. All field entries must be in ink of a distinctive color not used in these Records for any other purpose. Reference may be made to charts for the purpose of clarifying or amplifying the text, but not as part of the permanent record so far as the Coast Pilot Section is concerned. The chart-sections that are prepared as a permanent record are filed in the Nautical Chart Branch, and instructions for their preparation are given in **8521** and **9133***b*. Plans of completed or projected work should be obtained locally and submitted to the Office (see **2361**, **834**, and **916**, Blueprints and maps obtained locally).

Corrections, information, etc., should be written, or securely pasted or clipped in the blank spaces of the Field Record Book. The place in the text to which each entry refers should be clearly indicated by a leader or arrow or in some other clear and unmistakable manner. Clarity of meaning and definiteness are of supreme importance. A vague statement may be misinterpreted and result in an error, or its clarification may require laborious and time-consuming research or correspondence.

*c. Plan of work.*—It is worth while for the reviser to outline an approximate itinerary and plan before starting field work. Both road maps and general charts should be used, and a system of inspection should be tentatively adopted; that is, routes should be marked and the areas indicated for inspection by truck or boat. If the cooperation of the United States Coast Guard has been obtained, a call should be made on the District Commander to learn what areas can be inspected with the use of his equipment. It will then be apparent where a chartered launch will be required, and the necessary arrangements can be more intelligently made.

The use of ferries, and trips on coasting vessels, fishing vessels, etc., should be considered.

*d. Information required.*—Information on a great variety of subjects is required. So far as practicable these have been listed in **916** in alphabetical order, with notes to indicate and limit the amount of detail that should be obtained and published on each subject.

*e. Sources of information.*—Following is a list of organizations and officials who should be interviewed for the purpose of obtaining local information. Recommendations as to persons to be interviewed in an area should be obtained, if possible, before arrival there. Information from these, as well as from other sources, must be checked by the reviser. An actual inspection should be made in all cases where practicable.

When the information in the report is not checked by actual inspection, the source should be given, so that its value may be weighed against possible conflicting information that may be received at the Office.

- District Headquarters.
- Chart agencies.
- United States Corps of Engineers (District and local).
- Branch Hydrographic Offices.
- Maritime associations.
- Pilot associations.
- Fishermen associations.
- State organizations for port and waterway improvement.
- Port managers.
- Harbor masters, Harbor police.
- United States Coast Guard headquarters and all stations, including masters of lightships and tenders.
- United States Local Inspectors.
- Yacht clubs.
- Operators of repair yards and marine railways.
- County and municipal engineers.
- Towboat captains.
- Captains of coastwise vessels operating in the area.
- Individuals very familiar with the area, such as fishermen, old residents, and town officials.
- Engineers or officials in charge of water terminals (such as railroad wharves), or sewage disposal.

### *9133. Chart Inspection in the Field*

*a. Charting data.*—While inspecting a region for coast pilot revision, an excellent opportunity is afforded the reviser to note changes necessary on the charts and to obtain data for their revision.

While a reviser is not expected to have time to locate accurately all features necessary for chart correction, or to undertake actual surveys, much useful information can be submitted and frequently locations adequate for charting may be obtained without appreciable loss of time. But the fact that time does not permit the reviser to locate features should not deter him from furnishing information about changes. The information is useful as history and directs attention to the necessity for revision surveys.

The data submitted should consist of the following classes of information:

*Landmarks.*—To be added or deleted. Definite statements regarding deletion of landmarks should be made. A statement that a landmark is no longer prominent is not sufficient. (See **155** and **8534.**)

*Waterfront improvements and changes.*—Include condition, additions, and deletions of wharves.

*Bridges.*—To be added or deleted, including information regarding horizontal and vertical clearances of fixed bridges and drawbridges. Where new bridges are indicated on chart-sections, information regarding the roads leading to them should be furnished, if possible. (See **916**, Blueprints or maps obtained locally.)

*Removal of old piling.*—In marking wharves and bridges for deletion, information regarding the removal or existence of old piling should also be obtained and furnished to the Office. This is important, and the reviser should state definitely whether the information is sufficiently reliable to warrant deleting the feature or whether it should be retained as ruins.

*Rocks, shoals, and other obstructions.*—Include discrepancies between charted condition and actual condition which may be observed or reported. Local authorities should be consulted regarding the existence of uncharted rocks, shoals, or other obstructions of importance to navigation. Where it is not feasible to obtain the positions of such reported dangers, a report should be made to the Office, with recommendations for future surveys.

*Fixed aids to navigation.*—Include structures carrying airway obstruction lights, as well as other lights, such as isolated neon signs, which might be useful to the mariner.

*Geographic names.*—Include changes, additions, and deletions, giving authority. Use checkmark on chart-sections, if charted name is correct.

The coast pilot reviser has an excellent opportunity to verify charted names and to obtain new ones. Submission of such data should follow generally the instructions given in section **16**.

*Dangers charted.*—Include those charted as "Reported", "E D", and "P D".

*Channel depths.*—Include conditions of shoaling. Charted channel depths should also be checked with local information and, if possible, blueprints of the latest surveys should be obtained. If no recent survey exists, a statement of the present reported depth should be made, giving the authority. (See **916**, Channels.)

*Cable areas.*—Include locations of termini.

*Overhead cable crossings.*—Include clearances. (See **916**, Aerial cables and trolley wires.)

*Unusual characteristics.*—Of shoreline, such as colored bluffs or other features that may be useful as landmarks.

*Recommendations for new surveys.*—These should be made in a special report to the Office.

*b. Submission of data.*—The following procedure is recommended for submitting information regarding changes:

Note changes in the field on one set of charts, which set is retained by the reviser for field use.

Prepare a second set with notes relating to chart corrections. Cut these charts into letter-size sections, and forward them to the Office with a transmitting letter giving suitable explanations of the changes. After these are reviewed in the Division of Coastal Surveys for future investigations they are filed as Chart Letters in the Nautical Chart Branch of the Division of Charts.

In preparing the set of chart-sections for the Office, the reviser should bear in mind that landmarks, bridges, wharves, and other features cannot be applied to the chart without actual location. Merely spotting a feature on a chart is not sufficient. An effort should be made to locate the features, at least by sextant angles. If time does not permit this, and the feature is spotted or drawn in approximately, a note to that effect must be made on the chart-section, with an explanation in the transmitting letter.

The reviser should indicate definitely whether the features noted on the chart-sections were located or drawn with sufficient accuracy for charting. His judgment in this respect is more valuable than an Office interpretation. He should furnish all angles actually observed or state the method by which the feature was located. All corrections and notes made on chart-sections should be in red ink. (See also **8521**.)

### *9134. Inspection of Chart Agencies*

During the course of his inspection, the reviser shall visit the chart agencies of the Bureau to obtain and check information, and he will usually be required to make a complete inspection of these agencies. Special instructions are issued for agency inspections.

### *9135. Preparation of Manuscript*

The manuscript for a new edition of a Coast Pilot is completed in the Coast Pilot Section, except for stamping the type numbers, which is done in the Editor's office. The manuscript may be prepared for printing either by cutting and mounting the previous edition, or by typing. If the first method is used, the paragraphs should be separated by 1 inch or more for the insertion of corrections, additions, and type numbers. If the manuscript is typed, it should be double-spaced. Clearness will reduce the cost of typesetting and result in fewer corrections to the proof. Where a cross-reference is made in the manuscript, a memorandum should be made on the back of the page indicating exactly to what the reference refers.

The writer should be familiar with certain sections of the Style Manual of the Government Printing Office, and with the "Instructions for Authors and Illustrators," issued by the Division of Publications, Department of Commerce. If he is without prior experience in the preparation of manuscript for the printer he will find it advantageous to use an old manuscript as a guide.

The following paragraphs describe the manner of preparing the different parts of the manuscript and the order in which they are arranged for submission to the Editor:

### A. PRELIMINARY ITEMS

Before beginning the manuscript for the text proper, the following preliminary items are prepared:

(*1*) *Cover.*—This is a single sheet, on which is shown, in the desired position, the title for the outside of the finished cover.

(*2*) *Title sheet.*—This may be cut from a previous edition and pasted. The information on it should be corrected as necessary. The new serial number is furnished by the Editor.

(*3*) *Table of contents.*—This is prepared in the Coast Pilot Section. It should be accurate, as it is used by the Editor in marking the type numbers for the printer.

(*4*) *Chart index map.*—The one from the previous edition may be used as a standard, but it should be checked in the Nautical Chart Branch for changes in chart numbers and chart limits (see **916**, Chart changes). The names of all places used in chapter headings should be shown. All charts should be listed by number, and in numerical order, with their scales and prices. The limits and numbers of the adjoining charts and Coast Pilots should be shown on the index map. The title of the index map should include the title, the number and year of the edition, and the serial number of the Pilot. All changes to be made in the index map should be indicated on the standard, and it should be sent to the Division of Charts for reproduction. The Government Printing Office will requisition the number needed. Obtain an estimate of the cost for use on the printing requisition. The requisition for the Pilot should require that the index map be bound in place.

(*5*) *Preface.*—This should contain a brief statement as to how the information in the text has been brought up to date, and a general description of the method used in writing the Pilot. Considerable care should be taken to explain the method used in linking the text to the charts so that the reader may utilize immediately and to its fullest extent the information in the Pilot. The preface is signed by the Director and should be referred to him for approval. The date given is the date to which the Pilot is corrected (see **916**, Dating a Coast Pilot).

(*6*) *Important.*—This is a memorandum printed in bold-faced type. It must be less than one page in length, and it faces page 1 for convenient reference. It consists of brief statements explaining special features and units in the Pilot, in order to avoid repetition in the text.

### B. PREPARATION OF TEXT

The manuscript for the text proper is divided into chapters, the first three of which deal with information of a general nature affecting the region of the Pilot. Each chapter thereafter describes the area shown on one of the general coast charts; that is, a chart of the largest-scale continuous series on a coast, such as the 1:80,000 scale series on the

Atlantic Coast and the 1:200,000 scale series on the Pacific Coast. By dividing the text in this manner it is possible to show economically the numbers of these charts as part of the folio headings on each page. The chapters are subdivided into sections according to the layout of the largest-scale charts.

In writing some Pilots, such as those of southeast Alaska, where the topography of the region, and consequently the chart layout, is very complicated, it may be inadvisable to divide the text into chapters according to the layout of the pertinent charts. In such cases, the text should be divided by reference to the geographic features; as, the major entrances from the sea, the intervening sections of the outer coast, and the principal straits or sounds with their tributary waterways. (See **916**, Folio headings.)

(*1*) *Chapter 1.*—Government Services to the Navigator.—This chapter describes the functions of the various federal agencies concerned with navigation, and contains other information of value to the mariner that is not readily found elsewhere. Because such material seldom changes, it has been assembled into one chapter and plated so that it can be reprinted as Chapter 1 in all Pilots. The writer of a Pilot should avoid repeating elsewhere the information contained in this chapter.

When the chapter is revised, the order of arrangement may be changed, and information of a similar character may be added. Minor changes are occasionally necessary, but in making them it is first advisable to consult the Editor regarding Government Printing Office methods.

(*2*) *Chapter 2.*—This chapter contains information of a general character concerning the region described in the Pilot, such as local services, local weather, harbors of refuge, a generalized description of the inland waterways in the locality and those contiguous to it, and other information of the type given in chapter 1, but which is peculiar to the region. Information is also given on the extent to which navigation is affected by the presence of weirs, traps, log storage, etc., in use by local industries.

Finally, there is included information of most value to a stranger approaching the region, such as descriptions of offshore currents, banks, and dangers; and of the most prominent landmarks, the first landfalls, the general character of the coast, localities where wrecks are most common, and the condition of surveys.

Chapter 2 may be divided into two chapters if the extent of the material warrants it.

(*3*) *Chapter 3.*—This chapter consists of a brief description of the routes usually followed by vessels in approaching the region from offshore, in traversing the region, both offshore and coastwise, and in running from port to port. In general, routes covering more than one chapter of the text are described here. Where routes join those described in other Pilots, proper reference shall be made.

This information is followed by tabulated Directions with courses and distances to be made good on the routes described. (Local Directions are given in place in the text of succeeding chapters.) A standard form of tabulating these Directions (see following sample) has been adopted and should be used in all Pilots. Where Directions are given for a very long route, as in Alaska Coast Pilot, Part I, an additional column may be used to show cumulative mileages.

*Directions*

SAN DIEGO TO SAN PEDRO BAY AND TO SAN FRANCISCO

TABLE 1.—*San Diego to San Francisco*

[Charts 5101, 5202, 5302, 5402]

| Positions (*Reverse directions in italics*—read upward) | True courses | Distances |
|---|---|---|
| 1. **Point Loma Light,** bearing 45°, distant 2.4 miles. Chart 5101. | *Degrees* | *Nautical miles* |
| Direct | 320 | 81. 6 |
| *Reverse* | *140* | *81. 6* |
| 2. **Point Fermin Light,** bearing 35°, distant 1.9 miles. | | |
| Direct | 293 | 56. 0 |
| *Reverse* | *113* | *56. 0* |
| 3. **Anacapa Island Light,** bearing 202°, distant 1.8 miles. Change to Chart 5202. | | |
| Direct | 291½ | 61. 2 |
| *Reverse* | *111½* | *61. 2* |
| 4. **Point Conception Light,** bearing 25°, distant 2 miles. | | |
| Direct | 307 | 12. 8 |
| *Reverse* | *127* | *12. 8* |
| 5. **Point Arguello Light,** bearing 50°, distant 2.8 miles. Change to Chart 5302. If bound to San Luis Obispo, see Directions, page ----. | | |
| Direct | 329½ | 121. 1 |
| *Reverse* | *149½* | *121. 1* |
| 6. **Point Sur Light,** bearing 60°, distant 2.5 miles. Change to Chart 5402. If bound to Monterey, see Directions, page ----. | | |
| Direct | 336 | 58. 1 |
| *Reverse* | *156* | *58. 1* |
| 7. **Pigeon Point Light,** bearing 70°, distant 2 miles. | | |
| Direct | 339 | 36. 6 |
| *Reverse* | *159* | *36. 6* |
| 8. **San Francisco Lightship,** bearing 55°, distant 1 mile. If entering San Francisco Bay, see Directions, page ----. If bound northward, see Directions, page ----. | | |

TABLE 2.—*San Diego to San Pedro Bay*

[Chart 5101]

| | | |
|---|---|---|
| 1. **Point Loma Light,** bearing 45°, distant 2.4 miles. | *Degrees* | *Nautical miles* |
| Direct | 323 | 81. 0 |
| *Reverse* | *143* | *81. 0* |
| 2. **Los Angeles Harbor Light,** bearing 270°, distant 300 yards. To enter San Pedro Bay, see Directions, page ----. | | |

TABLE 3.—*San Pedro Bay to San Francisco*

[Charts 5101, 5202, 5302, 5402]

| | | |
|---|---|---|
| 1. **Los Angeles Harbor Light,** bearing 315°, distant 0.25 mile. Chart 5101. | *Degrees* | *Nautical miles* |
| Direct | 245 | 3. 7 |
| *Reverse* | *065* | *3. 7* |
| 2. **Point Fermin Light,** bearing 35°, distant 1.9 miles. Continue as per table No. 1 from position No. 2, Point Fermin Light, to San Francisco Lightship. | | |

(*4*) *Chapter 4 to Appendix.*—In chapter 4, the detailed description of the region begins. Each chapter is divided into sections according to the layout of the largest-scale charts of the area. The subjects to be described and the amount and type of information to be given regarding each are included in **916**. The sequence of description of the region should be geographically continuous as shown on the charts. The

description of each port should follow, so far as possible, the sequence given in **916**, Port information.

The Pilot should be written so the reader will be able to locate readily the names of features in the text and to determine the numbers of the largest-scale charts on which they appear. To accomplish this the features described in a section,

(*a*) Must be described as they appear on the largest-scale chart.

(*b*) Must be indexed where they are fully described. To avoid confusion and excessive indexing, they should be indexed elsewhere only for special reasons.

(*c*) Must be bold-faced under headings of the largest-scale charts, where they are fully described. If the names are used elsewhere, they are printed in ordinary type so that they will not be indexed there. This will make it obvious anywhere in the text which of the large-scale charts shows the feature being described.

This method of correlating the Coast Pilots with the charts not only makes the chart numbers readily available to the reader, but it also indicates the charts best suited to his needs. This promotes the use of larger-scale charts.

The method is illustrated by one of the chapters from Coast Pilot, Section A, Atlantic Coast, 1941 edition, the table of contents of which is as follows:

**Chapter 14. Cape Cod Bay**

[Chart 1208]



The chapter title in this case is the same as the title of coast Chart 1208 (scale 1:80,000), but this need not always be the case. There may be instances where it will be desirable to deviate from the chart title. (See also **916**, Folio headings.) Matters peculiar to the region covered by the chapter should usually be given here at the beginning of the chapter, except those requiring a knowledge of the text of the chapter, which should be given at the end.

Under the chapter title is given the first center head, "Plymouth, Kingston, and Duxbury Harbors (245)." These harbors are all shown on Chart 245 (scale 1:20,000), the largest-scale chart of them. The descriptions in this section give all the information required about these harbors, including such of the approaches as are shown on Chart 245. All names and features appearing on this chart that are to be indexed are bold-faced in this section, and only in this section. The reader is thus enabled to locate readily the names of the features in the text; to find the place in the text where a feature is fully described, by referring to the index; and to find the number of the largest-scale chart on which it is shown, by referring to the center head under which it is described.

The Directions to Plymouth Harbor include most of the Directions for Kingston and Duxbury Harbors. It is not necessary to make a center head of this, but it has been done in this case, principally because of the prominence of the harbor and because the Directions are given from points that are not shown on Chart 245. The numbers of the charts recommended for use in following these Directions are given in their proper places in the Directions in such a manner as to be most convenient for use.

Continuing south from the area shown on Chart 245, there is a section of coast shown on Chart 1208, which is on no chart of larger scale. This section extends to the eastern entrance of Cape Cod Canal, which is shown on Chart 251 (scale 1:20,000). Between Chart 251 and the Barnstable Harbor chart there is another section of coast shown on no chart of larger scale than Chart 1208.

The entire section of coast from the Plymouth Harbor chart to the Barnstable Harbor chart is described under the next center head, "Coast, Plymouth to Barnstable (1208)." All names to be indexed under this section are shown in bold-faced type. Those which are also on Chart 251 are shown in ordinary type since they will be indexed under that chart.

No description is given here of Cape Cod Canal, for it is described in full in a separate chapter. Even the controlling depth is omitted in this section, because its inclusion would mean an additional correction in the Supplement every time the controlling depth in the canal changed. For the same reason no mention is made of the depth through the canal in describing routes out of Boston. However, to preserve continuity in the text, the page where the canal is described in full is given wherever the canal is referred to.

Barnstable, Wellfleet, and Provincetown Harbors are shown on three different large-scale charts which join each other and there is no difficulty in following the adopted plan, in describing these places. Where the charts overlap and features are shown on both, it is not necessary to mention that fact. If the scales of the charts are the same, make the division at the most natural place.

The final section in this chapter, "Approaching Cape Cod (1208)," gives certain information of value to the navigator in approaching Cape Cod Bay. This section is center-headed and the chart number is shown as in the preceding cases. Such information can be combined with that given at the beginning of the chapter and placed either at the beginning or at the end.

(5) *Appendix.*—This comprises the final chapter of the Pilot, and includes in tabular form general information of a local character. An outline of the information that should be included is given below in the sequence to be followed. Other information of a similar character may be added. Except as noted, the data in all cases pertain only to the region covered by the Pilot in which they are published.

Coast and Geodetic Survey:
- Coast Pilots. (List all published by the Coast and Geodetic Survey, with prices.)
- District Headquarters. (List all maintained by the Coast and Geodetic Survey, with addresses.)
- Chart Agencies. (List the cities and towns in which Coast and Geodetic Survey chart agencies are located.)
- Distance Table. (Include information from Serial No. 444, giving local distances.)
- Planimetric Maps. (List those published or which will be published in the near future.)
- Variation of the Compass. (Include table of latest values, with annual change for various places in the area.)
- Ranges for Determination of Compass Error. (Include a table of ranges suitable for determining compass errors. See **916**, Ranges.)

Corps of Engineers:
- District Offices. (Give addresses.)
- Local Offices. (Give addresses.)
- Port Series. (Give numbers of volumes and titles.)

Hydrographic Offices. (List all Branch Offices with addresses.)

Coast Guard:
- District Commanders. (Give addresses.)
- Captains of the Ports. (Give locations and jurisdictions.)
- Buoy Depots. (List places where they are located.)
- Air Stations. (List places where they are located.)
- Radio Direction Finder Stations. (List places where they are located.)
- Lifeboat Stations. (Give names and locations of stations.)
- Hours of Operation of Fog Signals. (Give table.)

Customs Ports of Entry. (Give addresses, and designate those at which documents are issued.)

Immigration and Naturalization Offices. (Give addresses.)

Shipping Commissioner Office. (Give address.)
Fish and Wildlife Service Offices and Stations. (Give addresses.)
Public Health Service:
- Marine Hospitals. (Give addresses.)
- Relief Stations. (List by class, giving addresses.)
- Quarantine Stations. (Give locations.)

Harbor Masters. (List cities and towns having harbor masters and addresses of offices maintained; if there is no office, give where the harbor master is usually found, if the information is available.)
Yacht Clubs. (List names, with locations—*not* addresses.)
Marine Railways and Drydocks. (Give names of places having them and differentiate between marine railway, graving dock, and floating dock; give maximum size of vessel handled by each type at each place; note whether or not there is a machine shop in each case.)
Weather Bureau:
- Offices. (Give addresses.)
- Storm Warning Display Stations. (Give places and describe locations.)
- Meteorological Tables. (Give data for 4 or 5 well-separated places in region. Obtain from previous Pilot or Weather Bureau. See also Coast Guard.)

Conversion Tables, True to Magnetic Directions. (Give tables, using intervals of 2° and eighth points; must cover the range of variation for the entire region.)
Conversion Tables, Feet and Fathoms to Meters, and vice versa.

### *9136. Marking Manuscript for Editor*

Those words and phrases that are to be printed in capitals, bold face, or italics should be indicated by the writer of the manuscript himself. This must be done, section by section as written and while the information is fresh in mind, so that emphasis may be placed more readily and accurately where it belongs and only there. The size of the type will be determined by the Editor, who uses the table of contents as his guide.

All type marking for the printer is done by the Editor, who uses only one family of type, the "Century." This family has been developed by the Government Printing Office to give any size or style of type face desired. By using only one family of type, the expense of typesetting is greatly reduced.

Except for center heads, words should very seldom be printed in capitals. Center heads should be given in position, centered, and typed in capital letters in the manuscript.

Bold-faced type is used in the text to enable the reader to locate readily names and items of more than average importance, and it is indicated in the manuscript by a horizontal bracket over the word or words to be bold-faced. But too much bold face fails to accomplish its purpose and should be avoided.

The words "caution," "danger," "warning," "rock," etc., are sometimes printed in bold face to attract the reader's attention. All names and phrases to be indexed should be in bold face, as well as paragraph headings such as "Directions," "Supplies," "Pilots," "Ice," "Currents," and "Tide." The figures of recommended courses should be in bold face, as "**273°**."

Italics may sometimes be used in the text, as for the name of a vessel, but their general use is not recommended. All words to be italicized are underscored.

Tables are printed according to standard rules and no marking by the writer is required, except that the table heading is underscored if it is to be italicized.

### *9137. Requisition for Printing*

Form 757, in quintuplicate, is required. A sufficient number of copies should be ordered to last the life of the edition. If an underestimate is made and a reprint is required later, it can be made by the photolithographic process at a cost only slightly more than that of plating. Do not order plates ordinarily.

The exact full name of the publication must be shown wherever used. The serial number of the new edition is assigned by the Editor. Obtain the estimated cost of illustrations and enter it on the requisition. Note any unusual requirements, such as *binding in* the chart-index sheet (if not so specified, it may be stapled in), and numbering every fifth line for certain parts of the text without decreasing the width of the printed part of the page. Give the jacket number of any sections that are already plated for use, and describe.

### *9138. Galley and Page Proofs—Proofreading and Correcting*

It is very important that the galley be proofread by the writer or by someone familiar with the manuscript and coast pilot work. Corrections are indicated according to the Government Style Manual. A Pilot is brought up to date at this time by applying such information as has been received since the manuscript was completed. The date of the last Notice to Mariners used is considered the date of the Pilot, and is entered as such at the end of the preface.

It is essential that all corrections be made on the galley proof, as there are very strong objections to making any at all on the page proof. Corrections and additions are expensive, even to the galley proof, and should be kept at a minimum.

When proofreading the page proof, only the corrections and additions made to the galley proof need be checked.

Only essential corrections can be made on the page proof. No additions whatsoever should be made unless they are of unusual importance. Where additions are necessary, they should be made in a manner to cause as little resetting of type as possible. It is usually best to consult the Editor about this, because of his familiarity with printing procedure.

In proofreading, the author should always hold the latest proof, and the material should be read to him.

### *9139. Index*

The index is ordinarily prepared by the Editor. If it has to be prepared in the Coast Pilot Section, the work should be done by someone experienced in indexing, or a careful study should be made of a good index to see how cross-indexing is best done. The value of a Coast Pilot to the user depends largely on the accessibility of the information contained and the ease with which that information can be referred to the respective charts. It follows, therefore, that the index determines to a large degree the value of the Pilot, and the utmost care should be exercised in its preparation.

When the galley proof is received, all names and headings to be indexed are entered on cards of a convenient size, usually 3 by 5 inches with trimmed edges. One card is used for each name. The number of the largest-scale chart on which the feature appears is entered in parentheses after the name. Additional cards are prepared for cross-indexing as necessary. One card is used for each entry in the index. Charts are indexed by number in the same manner, and later the numbers of the pages on which they are described are added.

When the page proof is received, the page numbers are entered on the cards, after which all entries on the cards are checked. The original entries may be prepared by a stenographer, but they should be checked in the Coast Pilot Section.

After having been checked, the cards are arranged in alphabetical sequence, then numbered so that they may be rearranged readily if disturbed, and a typed copy of the

index is made and verified. This is forwarded to the printer with the page proof. It is not customary to require a proof of the index. This is proofread in the Government Printing Office.

## 914. Intracoastal Waterway Pilots

A Coast Pilot generally describes all of the navigable waters in the region covered, but there are special Coast Pilots in which this is not done. These Pilots usually describe some particular route, such as the Intracoastal Waterway.

The ordinary Coast Pilot includes descriptions of the waterways which combine to form the Intracoastal Waterway, but these descriptions are scattered through the book and mingled with the descriptions of the adjacent coast, inlets, and streams; and where there is a special Intracoastal Waterway Pilot they are given only briefly.

The Intracoastal Waterway Pilot consists of a continuous description of that waterway and very little else, except descriptions of channels or inlets that connect the waterway to the open sea.

The development of the navigable channels which form the system of intracoastal waterways is almost entirely in the charge of the United States Corps of Engineers, War Department. This agency maintains District Offices, each of which is in charge of the waterways in a specified area, and each issues, from time to time, a bulletin describing the condition of the waterways under its supervision. The Corps of Engineers also publishes two pamphlets, one describing the Gulf Intracoastal Waterway and the other, the Atlantic Intracoastal Waterway.

Coast Pilots of these waterways must differ in some respects from Coast Pilots of coastal waters. They must be written in a manner to permit the greatest use to be made of the reports of the United States Corps of Engineers. The form of these reports should be studied, and the Pilot should be written so that it can readily be brought up to date and supplemented by use of the reports. For this reason, statute miles are used instead of nautical miles.

These Pilots must be correlated with the Intracoastal Waterway charts, but this should not interfere with presenting much of the detail in the same form and order used in the Corps of Engineers reports. Otherwise the instructions for the preparation of the manuscript of Coast Pilots apply equally to the Intracoastal Waterway Pilots.

These Intracoastal Waterway Pilots, although published primarily for the use of small craft, must be written for the navigators of the largest vessels that can use the waterways. Information applicable only to vessels too large to use the channels should be omitted.

Very little detail should be given about the navigability of tributary streams. So much of the navigation is in shoal water that the range of tide is of the greatest importance. Where grounding is likely to occur, the character of the bottom should be noted. Warning should be given of localities where sloughing is likely to occur or where freshets and storms may tend to shoal the channels. Any areas where snags are likely to be encountered or where vegetation may affect navigation should be described. Certain kinds of information become of increased importance in these Pilots.

Many parts of the Intracoastal Waterways are marked with so many aids to navigation that great care must be taken to avoid overloading the Pilot with so many detailed descriptions of these that it will be impossible to keep it corrected. Changeable detail, particularly that concerning aids to navigation, must be avoided so far as practicable.

The use of the proper amount of detail and the development of the text so as to facilitate as much as possible the use of the reports of the Corps of Engineers in bringing the Pilots up to date are the most important considerations in writing the Intracoastal Waterway Pilots.

### 915. Supplements

The purpose of these publications is to bring the Coast Pilots up to date by describing the changes affecting the text that have occurred since the edition was issued, and also to give any additional information that is available and of sufficient importance to warrant publication.

Supplements are issued whenever sufficient material has accumulated, usually about once a year. Each Supplement supersedes its predecessor and must be complete in itself without reference to preceding Supplements.

An inspection of any current Supplement will reveal the methods used in preparing them.

The following general rules must be followed:

(1) Give the page and line numbers affected.
(2) Where most of the text of a sentence or paragraph in the Pilot is unchanged, give the correction by stating that certain words must be deleted or added.
(3) Where the majority of the text in the Pilot requires correction, give the correction by stating that certain sentences or paragraphs should be deleted and others substituted as given.
(4) Where new information is furnished, direct that additional sentences or paragraphs, as given, be inserted in the proper place.
(5) The rules for writing a Coast Pilot should be followed in preparing a Supplement.

### 916. Coast Pilot Glossary

In the following glossary, the various subjects to be treated in a Coast Pilot are arranged alphabetically with an explanation of the treatment and method of description to be used. All cross-references, unless otherwise indicated, refer to items in this glossary.

ABBREVIATIONS, SYMBOLS, ETC.—Use the Symbols and Abbreviations chart published by the Bureau (see fig. 189).

ADVANCE NOTICE.—When a Coast Pilot is to be revised, insert a statement in the Notices to Mariners, requesting interested persons to forward to the Washington Office any available information affecting the Pilot.

AERIAL CABLES and TROLLEY WIRES.—Give the minimum vertical clearance at mean high water. In the case of high-tension power lines, allow an appropriate safety factor and add a caution note.

If advance notice is required to have an overhead obstruction temporarily removed for the passage of a vessel, give the necessary details.

AIDS TO NAVIGATION.—Location, importance, and permanence are the factors that determine the detail to be given in describing aids. For information as to how to describe different classes of aids, refer to the name of the type of aid in question, such as buoys, lights, and beacons.

If aids are usually removed from their stations, or if the type of aid is changed, during the winter season, explain, but give only approximate dates, except where the Light List gives definite dates.

When referring to an aid, use the name given in the Light List (see **7843**).

In many places yacht clubs and local authorities maintain local aids during some season of the year. In such cases give a general statement to that effect, but avoid giving detail for, although such aids may be correctly located at one time, they may be differently placed the next season. Avoid making disparaging remarks. Do not name the local authority or give definite dates. (See also Buoys.)

AIRWAY BEACONS.—Note the existence of lighted airway beacons and give at least approximate positions. Note their prominence. State whether they are visible by day or night, or at both times. If they are near the coast, their elevations should be given, if available.

ANCHORAGES (in general).—A list of the best harbors of refuge for the area should be given in chapter 2 (see Harbors of refuge).

In describing anchorages in the text, give the value of each anchorage in various weather conditions. This depends in part on conditions that are not always to be determined from the chart. Obtain local reports on the value and accessibility of different anchorages under various conditions. Give depth and type of bottom, and state whether the holding ground is good or otherwise, if such information is available. Define by ranges or landmarks the position recommended as an anchorage, if possible. Give the controlling depth of water at the entrance. If the anchorage is subject to squalls, draws, or williwaws, or if the swell makes in, describe the conditions under which these phenomena occur, the precautions necessary, etc. If the anchorage area is likely to be crowded by other vessels or by moorings, describe the conditions, and state what part of the area is most likely to be clear. For remote localities, describe whatever communications may be available, distance to post office, etc.

ANCHORAGES, EXPLOSIVE.—The limits of these are shown on the charts, to which reference should be made. Navigators must obtain authority to use these anchorages from the Captain of the Port. Refer them to that official for the rules and regulations governing their use, which are changeable. Give only that part of the regulations that should be known before the Captain of the Port is consulted.

ANCHORAGES, SPECIAL.—Naval and yacht anchorages, special yacht basins, and special areas for unlighted vessels. Describe these in the same manner as other anchorages.

ANCHORAGE REGULATIONS.—Restricted anchorage areas are shown on the charts and should be defined by a reference to the chart. Rules that are changeable should generally be omitted; but important or unusual rules should be included. Refer the navigator to the Captain of the Port or Harbor Master for special regulations. In all cases give such of the regulations as a navigator without local knowledge must have to guide him until he can contact local authorities.

Anchorage areas may be restricted or forbidden by either the District Engineer or the Coast Guard. In some cases, publications describing the areas and giving the regulations of these agencies are issued free. Where this is the case, it should be noted in the Pilot, and the address at which the publication may be obtained should be given.

Use the anchorage regulations in the "Rules and Regulations Relating to the Navigable Waters of the United States," published by the United States Corps of Engineers, but see that they are correct to date. Reference should be made to this publication.

APPEARANCE OF COAST ON MAKING LAND.—General notes are to be given in chapter 2 (see Landfalls).

APPRAISERS STORES.—If there is one in the port, give the address.

APPROACHES TO HARBORS AND PORTS.—Give descriptions and sailing directions from offshore and from along the coast.

BANK.—This term when used with reference to the shore, refers to rivers only. (For its use in referring to an offshore feature, see Shoals. See also **1682**.)

BARS.—Describe the principal marks and aids to navigation. Give directions for approaching, with descriptions of outlying and other dangers, and how to avoid them. If the bar is dangerous, state under what conditions, and describe those most favorable for entering. Give the least depth and width at the best place for crossing the bar, and the most favorable time for crossing inbound. State if the bar breaks in ordinary or only in heavy weather, and how far out the breakers extend. Give the velocity and direction of wind, and the stage of tide producing these conditions. Give the character of the bottom. Give the changes in depth and shift in position, to which the bar channel and approaches are subject, if available. (See Channels.)

BEACHES.—This term refers to the strand; there is no beach on rocky shores. Note as much of the character of the beaches as is of value to the navigator. Describe places suitable for beaching a vessel.

BEACONS.—Describe location, shape, appearance, visibility under various conditions, and identifying marks, as the importance and value of the beacon warrants. Give the elevation. If lighted, treat in the same manner as other lighted aids. (See Aids to navigation.)

BEARINGS AND COURSES.—All courses given must be *true* and from 0° to 360°. Bearings also must be true, but may be either in degrees or points; where accuracy is required, use degrees.

Points shall be used only to indicate approximate or general directions. A table is included in the appendix of each Pilot for conversion of true directions in degrees to equivalent magnetic directions in points. (See Magnetic courses and bearings.)

Avoid so far as possible referencing courses to floating aids to navigation, such as buoys. If possible, refer them to some fixed prominent object, that is unmistakable, easily identified, and permanent.

Give danger bearings where important. Give bearings of ranges and channels.

Bearings to clear offshore dangers, etc., are given from seaward, but to locate offshore dangers or objects, they are given from landward. Light sectors are defined by giving bearings from seaward.

BLUEPRINTS AND MAPS OBTAINED LOCALLY.—From the U. S. Corps of Engineers and local authorities, such as State, county, or town engineers, it is often possible to obtain blueprints of surveys, and maps of harbors showing changes that affect the charts, as well as the Coast Pilots. This should be done where possible. It should be borne in mind, however, that such data, to be of value for correlation with existing surveys and charts of the Bureau, must be connected with the federal network of triangulation. Three well-distributed points, so connected, will ordinarily provide excellent control (see **2361**). For use in Coast Pilot revision only, such accuracy is not required, and the reviser should use his judgment as to what is needed.

A personal inspection of the area will generally be required to ensure that the map or blueprint shows actual conditions. State on the print whether this was done and note existing conditions plainly. (See **2361** and **834**.)

Many blueprints of surveys by the U. S. Corps of Engineers and other organizations are on file in the Office. Depths in channels and at wharves can often be found on these. Maps of harbors are sometimes made by local interests and copies may be available.

BONDED WAREHOUSES.—If available, describe facilities.

BOTTOM, CHARACTER OF.—(See Soundings.)

BOUNDARIES.—National or State boundaries should not be mentioned because of possible complications. Boundary monuments are sometimes landmarks and may be described as such. If information about boundaries is required, refer to U. S. Geological Survey Bulletin No. 817.

BOUNDARIES OF INLAND WATERS.—These are given in the "Rules of the Road," which are issued free of charge by the U. S. Coast Guard. They are not to be published in the Coast Pilots. (See Rules of the Road.)

BREAKERS.—Give location, limits, and stage of tide and weather conditions at which they break. State whether the rock or reef bares, how much, and at what stage of tide. (See Bars.)

BRIDGES.—Bridge data should be included in a table in the appendix. This table should include all bridges over navigable waters in the region, together with information that can be tabulated, such as, type of bridge, prescribed signal for opening, horizontal and vertical clearances at mean high water, which side of draw or bridge opening should be used, and depth of water below bridge, if pertinent. Bridge data for the most important ports, in which there may be a number of bridges, may be included in a table in the text where the port is described. These latter bridges should not be duplicated in the appendix, but reference should be made to the page of the text where they may be found.

Any necessary rules and regulations governing the operation of bridges should be included in the text. The reviser should obtain copies of such rules and regulations. It is essential that the Coast Pilot contain enough details to enable the mariner to make full use of the channel through the bridge, but details of no value to the mariner should be omitted.

Where there are a number of bridges in the same locality there will probably be enough of the regulations common to all or nearly all of these bridges, so that these regulations can be grouped and printed only once, noting the necessary exceptions.

Information regarding bridges can be obtained from two volumes, both published by the U. S. Corps of Engineers, which has jurisdiction over the construction and operation of bridges over navigable waters of the United States. One volume, "Rules and Regulations Relating to the Navigable Waters of the United States," contains the rules for operation of most of the bridges; and the other, "List of Bridges over Navigable Waters of the United States," gives the dimensions of the openings and other data. Copies of these, corrected to date, should be obtained. The U. S. Corps of Engineers is the authority for information regarding bridges, and where there is a discrepancy between data obtained in the field and those contained in these publications, the safer of the two should be used.

The reviser should make certain, while still in the field, that the necessary information for each

bridge is available. If not, he must obtain it locally or from the District Office of the U. S. Corps of Engineers.

BUNKERING.—This refers to water, coal, fuel oil, Diesel oil, and gasoline. The information given should describe facilities, quantities available, and the rate of putting on board ship. State whether a ship is bunkered while at anchor or alongside a wharf. Much of this information is contained in the Port Series. State also facilities for putting gasoline on boats; tank, drums, float, wharf, or truck. This is particularly important at isolated places. Oil barges are maintained at some localities for part of the year, and at some, gasoline is piped to landing floats used by launches, etc. Where there are facilities of this kind, they should be described.

BUOYS.—Their appearance or location should not be described in too much detail, as these are subject to change. It is usually sufficient to say that "The north end of the shoal is marked by a buoy." No more detail should be given in the description than is of actual value. Necessary details are given on the charts and in the Light Lists. If a description is considered necessary, use the nomenclature in **917**.

The numbers of buoys should not be given, except where necessary, as occasionally in writing Directions.

Depths at buoys should not be given except for a special purpose.

If buoys are reported to tow under at times, the navigator should be warned, and in some cases the conditions may be described, as spring tide or freshet.

Locally maintained buoys may not be dependable. They may vary in this respect from year to year, and so it is usually sufficient to say that "The channel is marked during the summer season by locally maintained buoys," without further comment. (See Aids to navigation.)

In some localities the type of buoy is changed during the winter season when they are endangered by ice. Where this is the case explain, but avoid being too definite, and avoid definite dates except where given in the Light Lists.

Mooring buoys are maintained in some harbors by port authorities or steamship companies. The general locations of these should be given, with necessary information as to their use, and whether charges are made.

If a yacht club maintains moorings for the use of visiting yachts, mention that fact, omitting detail subject to change.

Seaplane landing areas, torpedo ranges, etc., may be marked by buoys. In these cases, the general location, with a statement as to whether the buoys are lighted or not, and any rules affecting navigation should be given.

At some wharves onshore winds and seas are such that one or more buoys are maintained for laying off the wharf or for hauling off. If this condition exists, it should be described in detail, with such explanation of the dangers and ways of avoiding them as may be warranted. If conditions sometimes require the use of an anchor when going alongside, it should be noted, and the reason should be given.

Cargo is often discharged and received by vessels lying at a mooring or at anchor. If moorings are maintained for this purpose, describe them and their use, describing any conditions that may be dangerous, such as sudden changes of weather, sea from a certain direction, etc.

BUSH STAKES.—If used by local people to mark channels, that fact should be mentioned in the Pilot, but details must be avoided.

CANALS.—Describe location and approaches. Give the controlling depth and width, and state whether they are maintained or subject to change. Give the available length of each lock, capacity of locks, depth over sills, controlling vertical clearance under overhead structures, passing points, tie-up points, local contractions, variations of surface elevation, period open to navigation, toll charges, signals, and regulations governing operation. Also describe any currents, special anchorage basins provided, special aids to navigation, and special publications issued by canal authorities.

It is important to have the detailed description of a canal in one place, and only one place, in the text. If the same canal is referred to in other places in the text, do not give any details which will require constant correction in the Supplements. Use cross-references freely in such cases. (See **9135**B(4).)

CANNERY LAUNCH WAYS.—Mention in the text the location of any in isolated regions, giving the capacity, if available.

CAPITALIZATION.—Where such words as cape, point, island, etc., are used with a name, the initial letter should be capitalized. Thus, Montauk Point, Mt. Desert Island, Cape Cod, Point Conception, Gulf of Mexico. (See **917**.)

CENTER HEADS.—These are to be typed or lettered in capitals, and in place in the manuscript. The chart number is given on the second line immediately below, in parentheses and centered.

CHANGE OF SHORELINE OR DEPTHS.—Mention any reliable evidence as to recession or extension of shoreline or change of depths. Note important facts regarding changes observed. Give evidence, if any, of subsidence or emergence of shores. Locate and describe the limits of a dumping ground for dredged or other materials. Report all obstructions. Temporary obstructive operations, such as dredging or other rapidly changing conditions, should not be described. Obstructions that will remain for several years, such as those incidental to the construction of a large bridge, should be described. Note especially localities where changes of any sort affecting navigation are likely to occur, and report to the Office those which should receive frequent attention so that publications may be kept up to date.

CHANNELS.—In the Pilot give controlling depths of channels, widths if necessary, and the probability of change. Where dredging is mentioned, state if the channel depth is maintained by maintenance dredging. If the controlling depth given is not for the entire width of the channel as shown by the channel lines on the chart, give as much information as is warranted. In some cases the project should be described, and the extent of completion should be given, with the date. Give the character of the bottom. State whether the sides are defined, at high or low water, by spoil, color, marine growth, etc., and give light effects if they are of any aid in distinguishing the channel limits.

The reviser shall call at each District Engineer Office in the region covered by the Pilot being revised and obtain the most recent information available on the condition of the waterways under the jurisdiction of each office. The peculiarities of some of the dredged channels may be of great value. Tendencies to fill at certain places and the reasons for the filling, such as currents, current eddies, sloughing, floods, seasonal freshets, and ice, are important and should be explained in the Coast Pilot wherever such a condition is known to exist. If the depths are stable and changes affecting navigation are rare, explain. The extent of maintenance dredging is important. Where rock outcrops exist in dredged channels, with less water over them than the general dredged depth, it is important to state that the bottom is rock.

State the maximum draft known to have been taken through the channel. Where the maximum draft differs from the minimum depth in the channel, give the reasons, as swell, squat, tide, and rocky or soft bottom. Note the depth and character of approaches to wharves, piers, drydocks, marine railways, and coal stations, and give the manner of approaching them, and why. (For channels over bars, see Bars.)

Describe aids to navigation as necessary. In some well-marked channels, it will be sufficient in writing Directions to say to follow the aids. Usually it is better to give courses and distances for use in fog.

For emphasis it may be advantageous to give the least depth and its location in a separate paragraph.

Local information as to depths may not be dependable. Such information should be most carefully checked, by soundings, if possible. Refer to the file of chart standards in the Nautical Chart Branch, and then to the survey sheets, or to the blueprints of the U. S. Corps of Engineers, as may be necessary, to obtain information not yet shown on the charts.

If a special method of showing the depths is used on the chart, such as by quarter widths of the channel, the method used should be described in such detail as is necessary to make it clear.

If the depths change, or the position of the channel shifts so frequently that details of these changes are given in Notices to Mariners, either at regular or irregular intervals, include that information in the Pilot.

In describing channels of such width that objects on both sides may be used simultaneously by the navigator, the channel should be described as a whole. Otherwise, the descriptions of different sides or sections of the channel may be separated in such a manner as to conform best to the layout of the Pilot.

CHART CHANGES.—Before sending the manuscript of either a new edition or a Supplement to press, the Nautical Chart Branch must be consulted for changes in the limits of the charts or in chart numbers for the region being covered.

CHECKING.—The importance of checking the manuscript cannot be overemphasized. Unless this is done thoroughly, errors are certain to occur.

Every line of the manuscript, not only the parts that are changed, must be read and checked with the charts. The field reviser should use a system of checkmarks to indicate what he has checked in the field.

The recommended Directions should be checked with particular care. They must not only be scaled correctly, but they must follow the best routes. Survey parties are instructed to sound along all courses which they recommend (see **356**). Every course and distance scaled from a chart must be checked. (See Directions.)

It must be borne in mind that an error in a Pilot may have a very serious consequence. Coast Pilots are frequently used in law courts, and their accuracy must be beyond question. In fact, the first and most important requirement is accuracy.

The importance of accuracy is illustrated by the action of the Director of the Bureau of Marine Inspection and Navigation in the case of the grounding of the S. S. *Manhattan* in January 1941. In the list of findings of the Marine Investigation Board against the master is included, "He failed to heed the information and advice noted in Section **D**, United States Atlantic Coast Pilot with reference to making this approach."

COAST.—In general, this term refers to a strip of land of indefinite width bordering outside waters.

COMPASS ERROR RANGES.—(See Ranges.)

CONFIDENTIAL MATERIAL.—Material marked "Confidential" must be locked in the vault when not in actual use (see also **125**).

CONTINUITY.—Descriptions must be continuous. There must be no gaps. Gaps may be avoided by a special explanation or a cross-reference. (See discussion of Cape Cod Canal in **9135**B(4)). In a manuscript, each page must begin with a new paragraph.

COURSES.—The words "course" and "steer" must be used to mean "make good a course of." The latter is an awkward phrase to use continually, and the "Important" note (**9135A**(6)) should contain an explanation of this meaning so that the words "course" and "steer" can be used in the text without risk of being misinterpreted.

COURSES AND BEARINGS.—(See Bearings and courses.)

COVER.—A proof of the cover should be required, and it should be checked. The title shown on the spine of the book should be standard, that is, it should read from the bottom up.

CROSS-REFERENCES.—(See Page references.)

CRUISING.—Much of the information given in the Pilots should be obtained or checked from a vessel. The field reviser must use his judgment to make the most effective use possible of the floating equipment available.

CURRENTS.—(See Tides and currents.)

CUSTOMS.—Include in the appendix a list of addresses of customhouses. The text should contain a certain amount of information on this subject, varying with different ports. A statement should be made as to where the customs officer boards incoming vessels.

CUSTOMS PORTS OF ENTRY.—Besides being listed in the appendix, this information should also be given in place in the text (see Port information).

DANGER CURVE.—Note the depth curve that may be considered the danger curve, if conditions make this information of value.

DANGER ZONES.—From time to time the United States War and Navy Departments designate certain areas as danger zones, and publish rules and regulations for the control of all shipping within such areas.

Where practicable, the limits of these zones are shown on Coast and Geodetic Survey charts. The limits and regulations are usually given in a number of publications, such as the Hydrographic Office and Coast Guard Notices to Mariners and the Hydrographic Office Weekly Bulletin. The times that these areas are in use and are dangerous to enter are published in the Notices to Mariners.

In the Coast Pilots it is sufficient to give the general location, and refer to the specific chart for the definite limits. That part of the regulations of importance to navigation should be quoted or explained in the text, and reference should be given to the publications in which the times of use and other details are advertised.

DANGERS, INSHORE.—Give extent and nature; least depths over them; whether visible; if they break, at what stage of tide; how much, if any, is bare at the chart datum; marks or ranges for clearing them by day or night.

Describe any light effects on shoals or discolorations of the water that affect navigation.

In regions where dangerous shoal areas or pinnacles are marked by kelp or other marine growth, state the ordinary significance of such growths, at what stage of tide they show at the surface, and when, if ever, they are towed under.

In regions where boulders, ledges, coral heads, or similar dangers probably exist, it is very desirable to mention that fact. Where boulders are common, a warning should be given that vessels should avoid those places where the depth does not exceed the draft by so many feet.

There is no need to list each one of a number of dangers in a locality. A description of the most prominent, or possibly the one farthest offshore, with a general statement, will generally be sufficient. (See Bars.)

DANGERS, OUTLYING.—Describe and give Directions for clearing them.

DATE OF A COAST PILOT.—A new edition of a Coast Pilot is given the date to which it is corrected. This is usually the date of the latest Notice to Mariners used in correcting the proof. This date is entered on the galley proof at the end of the preface.

DATE OF INFORMATION.—Where information, such as depths in channels, or in docks, is subject to change, the date of the soundings, or information given, is very important. Generally both the month and year should be given, although the year alone is sufficient in some cases. (See Channels.)

DATUMS.—Refer depths and elevations to the same datums used on the charts of the region. Explain this clearly and unmistakably in the "Important" note (**9135A**(6)), and state what the datums are, as mean low water, mean lower low water, mean high water, as the case may be. Do not give the datums in the text, except for some special reason, as when some other datum is referred to. Abbreviations for datums may be used, but must be in accordance with the Symbols and Abbreviations chart (fig. 189), e. g., MLW, MHW, etc. An explanation of these abbreviations should be included in the "Important" note.

DEFENSIVE SEA AREAS.—Define by general statement or reference to the chart, and give the special regulations affecting navigation. These may be obtained from the Federal Register and the Notices to Mariners. The regulations may be grouped in one place and referred to elsewhere in the text.

DEFINITIONS.—Refer to "A Glossary of Sea Terms," by G. Bradford, and to the "Port Dictionary of Technical Terms," published by the American Association of Port Authorities.

DELETE.—A term which is much used but whose meaning is not as clear to some as the term "strike out." Use the latter in Supplements.

DEPTH AND DRAFT.—In general, give depths; there are exceptions, but care must be used in recommending channels for certain drafts, since it cannot be known what the condition of the sea may be or how a vessel will handle. There may be a number of special conditions under which a channel would not be safe for a draft that could be carried through it under ordinary conditions. In some cases *squat* or *list* must be allowed for. In river channels the freshness of the water is sometimes a controlling factor. (See Channels.)

DEPTH UNITS.—Use the same unit that is used on the specific chart being described, but omit the datum. (See Datums.) Do not give meters, but include conversion tables in the appendix. (See Meters.)

DERATIZATION.—If certificates are required or issued, explain the conditions. If regulations concerning rat guards, etc., are effective, include whatever detail appears to be required.

DETAIL.—Avoid including too much detail where not needed, as in channels that are well marked, even if they are winding. This type of sailing direction may be best handled in some cases by a simple statement to "follow the aids."

Too much detail may be confusing and involves too many changeable features. It is often impossible to keep such descriptions corrected in the Supplements.

DIRECTIONS.—The field reviser should obtain all possible information about different routes, established ranges, precautions that may be necessary on account of set of the current or lack of turning room, whether local knowledge is necessary, and whether any unusual caution must be observed.

Note all ranges or features that are of value in making courses good.

In Chapter 3 of the Pilot, after the description of routes, such Directions are tabulated that cover more than one chapter of the text (see **9135B**(3)). Local Directions (those included within any one chapter) for entering ports, etc., are given in place in the text with other information about the place referred to. Local Directions may be given either in paragraph or tabular form, but the latter should be avoided unless the Directions are of unusual length, since they cost more and usually give less information.

Local Directions should be headed, "Directions, ____________________", the name of the port or route to which they apply being always included. Where Directions are in paragraph form, the heading should be bold-faced as should all figures denoting courses. Important Directions, or those

of unusual length, or those involving a number of charts (as where Directions for a port are given from several points), may be center-headed. (See explanation of Plymouth Harbor Directions in **9135**B(4).)

Directions must be scaled with special accuracy and care. They must be plotted on the largest-scale charts, and the routes must be examined carefully to make certain that the recommended courses are safe and the best. In selecting routes, the writer must bear in mind that, although many vessels use certain cutoffs or special routes that may save them a little time, the Coast Pilot should recommend only routes that are safe and conservative. An able navigator, with local knowledge, can use many short cuts, but these should not be recommended to the general public. (See Two-way courses.)

All positions in Directions should be referenced to fixed objects of a permanent nature. In some cases it is necessary to refer to buoys, but avoid, as far as possible, the use of objects of a changeable nature or those whose positions are subject to change. Many changes in Supplements can thus be avoided.

Directions should not be given for channels that are so shifting in character as to make the Directions unreliable. In some cases they may simply consist of instructions to follow the aids as found, with a statement that the aids are moved as the channel shifts its position. Any known tendencies to sloughing, filling, or shifting of dredged channels should be described.

Tabulated Directions shall be given in the form illustrated in **9135**B(3).

(See Checking, and Port and starboard.)

DISCOLORATION OF WATER.—This should be described in detail where it may occur to such an extent as to affect navigation.

DISTANCES.—Distances should be given in nautical miles and tenths, or in yards where greater accuracy is required. In the Intracoastal Waterway Pilot, follow the system of the U. S. Corps of Engineers, which is statute miles. Do not use fractions; the graphic scales on the charts are in decimals. The lengths of short courses in Directions may be given to the nearest 0.05 mile. In giving lengths of measured trial courses, use as many decimals as are necessary for accuracy.

DOCKS.—A dock is the slip or waterway between two piers or projecting wharves. (See Wharves.)

DOCK CHARGES.—State if they are made, but do not give the rates.

DOLPHINS, PILES, ETC.—If of importance to navigation, mention their approximate locations and use; whether for tying up to, for storage, for working off wharf, etc.

DRYDOCKS.—(See Marine railways.)

DUES—PORT, DOCKAGE, PILOT, ETC.—These are generally too changeable to permit their quotation. In some cases, where fixed by law, it is permissible to quote in part if considered desirable.

ECHOES.—(See Sound reflection.)

E. D.—(See P. D. and E. D. dangers and soundings.)

ELEVATIONS.—Refer elevations to the same datum used on the charts, e. g., mean high water (see Datums). Give known or estimated elevations in all cases where the information may be of value to the navigator. This is of particular importance where the elevation will help identify a landmark, an offshore rock, etc.

FACILITIES.—Facilities for handling cargo should be briefly noted. The purpose is to inform ship officers if they must be prepared to use their own cargo gear. Give the rate at which coal and oil are loaded, and whether fuel and water may be taken at the wharves. (See Bunkering.) List the general facilities available, such as electric power, stevedores, rail connections, etc.

FERRIES.—The reviser may find it advisable to take trips on some ferries to note the routes followed and to obtain information from their captains. It is desirable to note in the Directions the localities where ferries usually cross main steamship tracks. This information may be of considerable value during fog.

Information should be given as to the kind of ferry, whether passenger, freight, or automobile, and ports at which ferry service is available. This is of particular importance in comparatively isolated regions.

FIELD WORK.—The reviser in charge of the field inspection shall ascertain whether the various divisions of the Bureau desire him to do any special field work, and also shall report to the Bureau on needs for surveys. Reports by individuals and organizations that field surveys are needed should be supported by evidence of the need. The reviser should recommend further surveys on account of developments, shoaling, changes, wrecks, reports of obstructions, inadequacy of old surveys, etc.

FISH AND WILDLIFE SERVICE.—If either federal or State bureaus maintain local offices in the district in which a reviser is working, he should obtain the addresses for the appendix of the Coast Pilot, and inquire of the officials in charge for their regulations, as well as for general information. Report any of their activities or regulations that may affect navigation.

FISH TRAPS AND LOBSTER POTS.—Note presence and season, where they affect navigation. If old stubs, broken off stakes, or piles are a menace, the localities and conditions should be given in the Pilot. Describe the general situation in the area in Chapter 2 of the Pilot.

Limits of fish-trap areas in many localities are shown on the charts. Refer to them when describing the region, but do not give their exact boundaries; generalize them. Special areas reserved for these purposes should be described, with a warning to navigators to keep clear.

FLOATING DRYDOCKS.—(See Marine railways.)

FLOATING LOGS AND OBSTRUCTIONS.—These are frequently found in sufficient numbers in certain localities as to constitute a danger to the navigation of small craft. Where such is the case, the Coast Pilot should warn the navigator.

FLOATS.—Private or public; this does not include every bathing float and private pleasure pier. The locations of public floats that are available to strangers should be given. Give depths at public floats. If there is no public float, and a private float is commonly used, give the depth there. State whether stores may be taken at a float; and if water, oil, and gasoline are piped to the float; if not, explain how they can be obtained. For isolated regions be more explicit about stores, and state whether ice is available.

FOG SIGNALS.—Give kind, but omit characteristics. At some wharves and yacht clubs special fog signals are operated, which should be described. Note silent zones as "reported," unless the evidence of their existence is unusually well established.

FOLIO HEADINGS.—These are the headings that are printed at the top of each page. Instructions to the printer are written by the Editor on the first page of the manuscript, and are repeated on the first page of both the galley proof and the page proof.

For several reasons, including economy, the chapter title, plus the number of the general coast chart (see **9135**B for definition), the area of which is described in the chapter, is used as a folio heading for all pages in each chapter.

Where the topography of a region is so complicated that it is not practicable to divide the Coast Pilot into chapters, according to the layout of the charts, another system of folio headings must be used. In general, the same principle as noted above should be followed so far as practicable. The same folio heading should be used for a number of consecutive pages. Folio headings should be selected according to the areas shown on the general coast charts, and wherever possible, the number of the general coast chart should be shown in the folio heading and the number of the largest-scale chart in the center head. In some cases it may be preferable to use other headings than shown on general coast charts.

FOREIGN TRADE ZONES.—Give the locations of such zones as are in the area; otherwise do not mention them.

FREIGHTERS.—In some regions revisers, while traveling from port to port, have found officers of coastwise vessels and terminal officials of the freight and passenger lines to be among the best sources of information.

GEOGRAPHIC NAMES.—These should be spelled as they are on the charts. This is to facilitate reference from the charts to the Coast Pilots, and vice versa. The origin and date of the chart should, however, be considered, and if the spelling appears of doubtful authority, the Division of Charts should be consulted. Inquiry should be made concerning charts in preparation and under revision. Consult the geographic name standards in the Map Hall. (See **9321**.)

Decisions of the U. S. Board on Geographical Names should be followed without waiting for the approved form to appear on the charts. In cases of disagreement or changes in names, obtain data which can be submitted to the Board for a decision. (See section **16**.)

The names of aids to navigation must be identical with those in the Light Lists (see **7843**).

Where a place is known by more than one name or by variants of the same name, the alternate names should be given in parentheses after the accepted chart name. But this should be done only in the part of the text where the main description of the feature is given; elsewhere, the chart name alone should be used. All names should be indexed.

As many geographic names as practicable should be included in the index, even including some names which may not need to be mentioned in the text for other reasons.

Keep a record of authorities for new names and proposed changes in names (see **162** and **163**).

GRAVING DOCKS.—(See Marine railways.)

GRIDIRONS.—State where these are available alongside wharves for docking small craft between tides. Beaches where small craft are commonly beached, or that are especially suitable for this purpose should be mentioned.

HARBOR MASTERS.—The harbor master, if there is one, is likely to be one of the best sources of local information. A special effort should be made to contact this official. He is most likely to know definitely the rules or regulations of the port that are in effect. He is also likely to be exceedingly well informed about local changes, and it is desirable that amicable relations be established with him so that he will be willing to furnish information to this Office by mail, if desired. The fact that there is a harbor master should be noted in the text, under the name of the port, and the port should be listed in the table of harbor masters in the appendix.

In small towns the harbor masters change so frequently that it is not practicable to list the latter by name. The list in the appendix, however, should include the name of each town having a harbor master and the address of his office if one is maintained, or, if not, the place where the harbor master may be usually found.

HARBOR REGULATIONS.—Those parts of harbor regulations that are of value to the navigator should be given. Special regulations for the control of certain industries should not be given except as they apply to navigation. As an example of this, consider the detailed regulations to control the handling of oils. Fuel oil, gasoline, and other oils are practically always handled by specialists. They are familiar with the regulations and are informed when changes are made. There is no need to include regulations of that kind in the Pilots, but the navigator should be warned of any precautions that he is required to take when bunkering or handling oils.

Information should be given as to where harbor regulations may be obtained and where the official responsible for the regulations and their enforcement may be contacted.

HARBORS OF REFUGE.—List in Chapter 2 of the Pilot, under local information, the best harbors of refuge in the region. Give full description in the proper place in the text, with information as to accessibility under difficult weather conditions. Give depth in channel and in harbor, character of bottom, peculiarities of weather, amount of protection afforded, security, swinging room, etc. (See Anchorages in general.)

HIGHWAYS.—State what highway connections there are in isolated localities.

HOSPITALS, MARINE.—Give locations of these in the text and list them in the appendix. If the Public Health Service has no hospital of its own, mention any other hospitals; in some cases give the location of and distance to the nearest Marine Hospital.

HYACINTHS, GRASS, WEED, MARINE GROWTHS, ETC.—State to what extent they affect navigation.

ICE.—The extent to which it interferes with navigation and the approximate dates between which this condition usually exists should be given. Describe in detail, giving effect of wind, kind of ice, whether channels are kept open by ice breakers, and to what extent aids to navigation are affected. Describe average conditions, but give additional information about conditions in the most severe winters, if available.

ILLUSTRATIONS.—In the Pilots now published by the U. S. Coast and Geodetic Survey, there is little, if any, need for illustrations. The comparatively complete charts and system of aids to navigation are sufficient for navigation without illustrations, except in a very few regions. Of these regions it is very difficult, if not impracticable, to obtain illustrations of value. Illustrations of well-known and easily recognizable features should not be used; they are not worth the expense.

The title of any illustration published should include the bearing and approximate distance of the feature from the camera station.

INLAND RULES.—(See Rules of the Road.)

INTRACOASTAL WATERWAY.—The amount of information that should be included in the general Coast Pilots regarding the Intracoastal Waterway, and in the Intracoastal Waterway Pilots regarding the coastal areas, will be determined by the writer for each area. Generally Coast Pilots should contain descriptions of the inlets and waterways leading to the ports at which vessels engaged in coastwise trade call. If there is an inside route from these ports to the other ports, that fact should be stated and the controlling depth given, but details must be omitted. A cross-reference should be made to the Intracoastal Waterway Pilot, where the route is fully described. In this way detailed correction will need to be made in only one publication, thereby simplifying the problem of keeping the Pilots up to date.

The Intracoastal Waterway Pilot should describe the inside passage, and briefly the channels and inlets extending from it to the sea, but should not give coastal descriptions, or more than refer to ports not located on the route or reached by it. (See **914**.)

JETTIES.—State if jetties cover and are dangerous, and at what approximate stage of the tide. Describe, as warranted by their value for protection, for landmarks, and as dangers, if so. Give height above mean high water.

KELP.—Where important, the extent of kelp beds should be given. If it grows on shoals, it should be described. Include appearance, quantity, whether seasonal or not, whether it tows under at times, and how it shows. (See **3623*b*** and **7864**.)

LANDFALLS.—First landfalls are described in Chapter 2 of the Pilot. Local descriptions are given in place in the text. Describe the appearance of the coast on making the land—on a bold coast the headlands, peaks, etc., with their form, color, and height; and on a flat coast, the water tanks, spires, beacons, etc. Streaks of color in bluffs, etc., may be useful identifying features. Mention any local features that may be used in fog or at night if the aids to navigation are not functioning.

LANDING FIELDS.—Report any in the locality visited. Any of importance to navigation should be described in the Pilot; for example, seaplane landings at which supplies are available, or that affect navigation. Mention regular routes and special services available in isolated places.

LANDING PLACES.—These are of special importance on dangerous coasts. State location and peculiarities affecting landings, stage of tide best for landing, and when dangerous, etc.

LANDINGS.—State whether public or private. If the former, give the depth of water alongside and in the approach. State whether fuel, water, and supplies are available and how they are taken on board. (See Floats.)

LANDMARKS.—Instructions for obtaining and furnishing information on landmarks by regular survey parties are given in **155** and **8534.**

Describe all prominent landmarks likely to be of most use for navigation or for future survey operations. If objects, such as mountains, hills, cliffs, islets, or rocks, are recommended as landmarks, give their measured or estimated heights. State if mountains mentioned are often cloud-capped.

Check in the field landmarks shown on charts or mentioned in Pilots, and report those that are no longer of value. Landmarks may be located by sextant angles. If new landmarks suitable for charting exist, select and locate them. Those sighted and recommended for charting, but not located, should be reported to the Office for future location. All landmark information shall be reported on Form 567 in accordance with **8534.**

LANGUAGE.—Simplicity, clarity, and conciseness are essential. No ambiguous or indefinite expressions should be used. The text should be clear even to a landsman going to sea for the first time.

LATITUDES, LONGITUDES, AND CHART NUMBERS.—About once each two pages in the text, one feature shall be selected and marked with an asterisk. The footnote shall consist of the latitude and longitude of the feature to the nearest tenth of a minute and the numbers of all the Coast and Geodetic Survey charts which include that position. Latitudes and longitudes of lights and other features are not to be given in the text, the need being fulfilled by the footnotes.

LIFEBOAT STATIONS.—Include in a table in the appendix all Coast Guard Lifeboat Stations in the region and their locations, and mention each with location in the text. Indicate those that are inactive.

LIGHTHOUSES.—(See Lights.)

LIGHTS.—Fixed lighted aids to navigation shall be called "Lights" in the Pilots, and the name given in the Light List shall be used and bold-faced in the text. With the description of the light, consisting of its elevation and the distance it is visible, shall be given a description of the structure supporting it, including, if necessary, adjacent structures. This description shall include all details of the appearance of the structure that might aid in identifying it in daytime, using the same nomenclature used in the Light List. Omit color of light, characteristics, phase, period, and sectors, except in unusual cases. Give types of fog signals operated, but not the characteristics. The term "lighthouse" is not to be used as a part of the name of the aid to navigation, but it may be used in the description of the structure, or a house or tower no longer used to show a light may be referred to as an "abandoned lighthouse tower" or an "abandoned lighthouse." Use the term which is most descriptive.

LIGHTSHIPS.—Give the appearance by day, identifying marks, number of masts, etc. Give the number of lights, elevation, and distance visible. Omit changeable characteristics, as in case of other lights. State type of fog signal operated, but not the characteristics. If auxiliary lights and fog signals are used in emergencies, describe them in the same manner. Describe any lights, etc., used to show the heading of the lightship.

LOBSTER POTS.—(See Fish traps and lobster pots.)

LOCAL MAGNETIC ATTRACTION.—Information of this kind should originate in the Division of Geomagnetism and Seismology. Local reports from the field should be forwarded to that Division for verification and information. Include in the Coast Pilot the location, limits of area involved, and maximum magnitude of error.

LOCKS.—(See Canals.)

LOG BOOMS.—Note where and when they may exist, if of interest to navigation. If the natural width of the channel is restricted by them, or if some areas are enclosed by them to the extent of affecting navigation, describe the condition. State if they are lighted.

LOG RAFTS.—State if the navigation of a channel or canal is affected by these or if their presence as tows may be a danger during fog or poor visibility.

MAGNETIC COURSES AND BEARINGS.—Tables shall be included in the appendix to facilitate the conversion of true directions in degrees to magnetic directions in points. These tables should convert true directions for every 2° into magnetic directions to the nearest eighth point, and should cover the range of variation in the region described in the Pilot. In most Pilots, the magnetic directions in points can be given for every 2° of variation, but in some regions the range of variation is too great for this. In such cases, the tables need not be made larger, but the directions in points may be given for only every 4° or 5° of variation, as necessary.

MAPS.—(See Blueprints and maps obtained locally.)

MARINE RAILWAYS.—Give a description under each port where there is one or more. Give maximum length, depth forward and aft, and tonnage of vessels that can be hauled out. Also give the controlling depth in the channel to the plant. State if there is a machine shop, and, if so, give a very general statement as to its capacity. Give the same information for floating drydocks and graving docks.

The table in the appendix shall give the dimensions, as above, of the largest vessel that can be hauled out on a marine railway in every port, in the region covered. Similar information shall be given in the same table for floating drydocks and for graving docks. State in each case if there is a machine shop. More detailed information may be given in the text if desirable. (See Repair Yards.)

MARKER BUOYS.—Mention where used.

MEAN LOW WATER, MEAN HIGH WATER, MEAN LOWER LOW WATER, ETC.—(See Datums.)

METERS.—Some navigators are more familiar with the metric system than with the English system of measurement. For their convenience there shall be included in the appendix suitable tables for the conversion of feet and fathoms to meters, and vice versa.

METEOROLOGIC CONDITIONS.—Tables shall be included in the appendix giving the best average information available for four or five different places. Obtain data from the Weather Bureau and Coast Guard.

MEASURED SPEED TRIAL COURSES.—To be referred to as such, unless the length is exactly 1 mile. Give the exact length and course, and state whether the length is in nautical or statute miles. Describe the appearance of marks, and give any other information of value to the user. Request other vessels to keep well clear of the course while trials are being run.

MOORING BUOYS.—(See Buoys.)

MOUNTAINS.—Any hill more than 1,000 feet in elevation should be referred to as a mountain. If snow-covered, state when, and give the elevation of the timber line. State whether the summit is usually visible or cloud-capped. Give any details that may aid in its identification or that may make it of unusual value.

MUD ISLANDS.—Where these occur, as off the Mississippi Passes, describe them.

NAMES.—(See Geographic names.)

NUMBERING OF LINES.—In the part of the text where the detailed description of the region is given, every fifth line should be numbered. Generally this will be from chapter 4 to the appendix. This facilitates text references, particularly in the Supplements. (See **9137** and **915**.)

OBSTRUCTIONS.—Where information is based on reports, or is of an indefinite character and not determined by a survey, give dates, with all pertinent information. If it is from an unverified report, state so.

OBSTRUCTION LIGHTS.—These should be described if they are used, and as much detail as necessary should be included.

OYSTER CULTURE BEDS.—The general location of these should be given, with a proper warning about speed and wash in the locality.

PAGE REFERENCES.—These are supplied by the Coast Pilot Section and entered on the page proof. Cross-references are essential in many places, but should not be used indiscriminately. In a complicated area, like southeast Alaska, a great many will be required, but on a straightaway coast, there need be very few. In some cases considerable repetition may be avoided by using them.

PARAGRAPHS.—Each page of the manuscript must start with a new paragraph. This is a requirement of the Government Printing Office Style Manual. If a paragraph is too long to go on one sheet, add to the length of the sheet. Short paragraphs are desirable.

P. D. AND E. D. DANGERS AND SOUNDINGS.—Give available information, with date. Give extent of investigation made, if any.

PILES.—Piles are sometimes left in place when a bridge or structure is removed. In such cases the condition should be described in the Pilot. (See Dolphins, piles, etc.)

PILOTAGE.—State whether it is required by law or is necessary because of difficulties of navigation for strangers. Give information as to whether pilots take vessels at night; where ships are boarded; description of pilot boat and signals; and location of cruising ground. State if prior or special arrangements can be made for pilots, and describe how they can be made. Copies of State and local Pilot Rules and Regulations should be obtained and used as authorities.

Give special regulations of importance. Describe where to anchor while waiting for a pilot, and state if tug is available and used for towing, docking, and shifting berth. Pilot rates and charges should not be given.

State whether a vessel is liable for payment of fee if pilot is not taken and give any exceptions. It is not necessary to give all of the details of the pilot regulations, but that part of value to an incoming stranger should be given.

POPULATION.—The population of the various ports described in the Pilot should not be given unless that information serves some special purpose.

PORT AND TERMINAL CHARGES.—Too much detail of a changeable nature must be avoided. It is usually sufficient to state that charges are or are not made for certain services. (See Port Series.)

PORT INFORMATION.—The following data are commonly required for each port described in the Pilot. So far as practicable this information should be given in the Pilot in approximately this order for all ports of commercial importance. If the port is described in the Port Series of the U. S. Corps of Engineers, a reference may be made to that publication, and some of the information in the Pilot may then be more generalized, but the fact that it is so described does not lessen the responsibility of the reviser to include in his record all information essential to the safe navigation of a vessel entering the port. All details must be included for any port regulations which the navigator should know before arriving at the port. Give the address of the office of port administration.

- General description of port:
  - Location.
  - Landmarks.
  - Channels, depths, etc.
  - Dangers.
  - Pilotage.
  - Towage.
  - Quarantine (fumigation).
  - Customs.
  - Port of entry.
  - Marine documents, if issued.
  - Immigration.
  - Hospitals and Relief Stations.
- Anchorages:
  - Quarantine.
  - General.
  - Forbidden.
  - Government vessels.
  - Explosive.
  - Special (yachts, etc.).
  - Mooring buoys.
  - Regulations, if important.
- Harbor Regulations.
- Tides.
- Currents.
- Bridges:
  - Clearances.
  - Signals.
  - Regulations.
- Directions.
- Port Services:
  - Dockage and wharfage.
  - Facilities.
  - Storage.
  - Supplies:
    - Fuel; oil, Diesel oil, gasoline, coal, provisions, water, and electricity.
- Lighterage.
- Salvage and wrecking gear.
- Marine repairs:
  - Drydocks, capacities, etc.
  - Shops.
- General port activities: Type and kind of commerce.
- Communications.
- Government offices.
- Ranges for compass adjustment.
- Weather:
  - Fog.
  - Prevailing winds.
  - Storms.
  - Ice.
- Storm warnings.
- Time signals, visual.

While the above outline is primarily designed for ports, it should also be followed in describing bays and other bodies of water as far as practicable.

PORT AND STARBOARD.—Avoid the use of these terms as much as possible by giving the direction or bearing of the object in degrees or points. Use a definite statement that is independent of the vessel's heading.

PORT SERIES.—These publications contain much information of value to the reviser. If the edition being used is of recent date, the information therein can be accepted. If the publication is old and out of date, verification of information of a changeable nature is necessary.

PORTS OF ENTRY.—(See Customs ports of entry.)

POST OFFICES.—If there is no post office at a landing, village, harbor, etc., in an isolated region, that fact should be mentioned. In such cases, give the distance to the nearest post office.

PRIVATE AIDS.—If they are maintained locally, they may be mentioned as such, but details must be avoided. (See Aids to navigation.)

PROJECTS.—It is sometimes advisable to give details of projects, such as those of the U. S. Corps of Engineers; for example, where maintenance dredging is done, or where work is incomplete at the time the Pilot is written but dredging is in progress. Under no circumstances should the project depth be reported as existing, until definite information has been received from proper authority that it does actually exist.

PUBLICATIONS.—It is intended that the list of publications in Chapter 1 of the Pilot shall include the titles of the official publications of value to navigators. Only information of a permanent kind should be given about them. The exact title of the publication and the place where it can be obtained are usually sufficient.

The field reviser should obtain copies of publications issued by port authorities, port commissions, pilot associations, yacht clubs, and other similar organizations which give information on subjects that should be treated in the Coast Pilot.

QUARANTINE.—Give any special features of the quarantine regulations that a shipmaster should be acquainted with before being boarded. Describe the quarantine anchorage and give the location where the quarantine officer boards vessels. Describe any special signals.

RADIO.—This subject is almost completely covered in Chapter 1, as far as the Coast Pilot is concerned. Sufficient information is given there for a ship officer to be independent of the radio operators for information concerning his own legal responsibility for his radio, and concerning the radio services available to him. It is not a function of the Coast Pilot to include a radio operator's manual. Call letters should not be given. Wave lengths may be given in certain instances when they are unlikely to be changed, and are of sufficient importance. Reference to H. O. 205 and H. O. 206 should be made freely.

RADIOBEACONS.—Give location and refer to Light List and H. O. 205 for details.

RADIOBEACON BUOYS.—Note the location and name. Refer to the Light List as necessary for details of operation.

RADIO DIRECTION FINDER STATIONS.—These should be mentioned, and reference made to the Light List and to H. O. 205 for details.

RADIO DISTANCE FINDING.—If stations are equipped for this method of distance finding, give that information in the text with any necessary references.

RADIO TOWERS.—Should be described like other landmarks. Include lights and elevations.

RADIO TELEPHONES.—In regions where shore radio telephone stations are few, or some one is of particular importance, give details, except those of a changeable nature.

RAILROADS.—State if there is a railroad siding on a wharf, or if cargo must be trucked. If trucks are run on the wharf, describe the condition.

In small ports, state if there is a railroad connection and, if not, how far it is to a railroad or truck line.

RANGES.—Do not give the characteristics of the lights, but describe the marks to facilitate identification in the daytime. Give bearing or azimuth of range. Where azimuths of ranges have been determined with sufficient accuracy for use in determining compass errors, the azimuths are given in degrees and minutes in the Light Lists, and the Coast Pilot should mention this fact in describing the range. Unless given to minutes, the determination is not suitable for such use.

A list of ranges suitable for compass-error determination should be given in the appendix. In this list should be given the Light List name and the description of each range mark, the true bearing to minutes, the variation at the place for a definite year and the annual rate of change of variation.

If the use of apparently suitable ranges is not recommended because of local attraction, or for other reasons, the condition should be described in the text.

Describe ranges in use by pilots and the means of identifying them. Suggest other ranges that will be useful. Give ranges to clear dangers, if available. (See Aids to navigation.)

REEF.—A reef is a rocky or coral elevation dangerous to surface navigation, which may or may not be exposed at the chart datum. A rocky reef is always detached from shore, while a coral reef may or may not be connected with the shore. It is important that the stage of tide be given at which a reef bares or breaks. The area that bares at the chart datum may be estimated, and a statement may be made that it bares so many feet at that plane. Peculiarities, such as light effect, etc., should be included. (See Dangers, inshore.)

RELIEF STATIONS, PUBLIC HEALTH.—Give locations of these in the text, and prepare lists for the appendix according to class.

REPAIR YARDS, ETC.—In addition to the information given in the text and in the appendix for the larger marine railways and drydocks at each port (see Marine railways), it is desirable to describe in the text, under the port name, special facilities for repairing small vessels. The maximum sizes that can be accommodated should be given, including the length, depth forward and aft, tonnage, and often a statement of the draft that can be taken to the dock. It is important to state if machine shops are available, and whether they are equipped for more than minor repairs to small boats. State if supplies are available at repair yard.

REPORTS.—When it is impossible to verify them, important corrections should be entered as reports. In some cases the source and date of the report should be given.

RIVERS.—Give controlling depths and the class of vessels which can enter, upstream limit of tide, depth on bars and permanency of channel, strength of current, anchorages, effect of freshets, distance to head of navigation for steamers and other craft. State whether water is fresh and suitable for boilers. Give Directions, and information necessary or of value to the navigator. If channel is very well marked, a statement to "follow the aids to navigation" may be nearly all the Directions required. (See Channels.)

ROUTES.—Reviser should ascertain and report the routes generally followed by vessels of various classes, powers, and sizes. These routes should be described in Chapter 3 of the Coast Pilot.

RULES OF THE ROAD.—Do not publish these—they are issued free of charge by the U. S. Coast Guard. Where special rules apply, describe the condition with as much detail as warranted.

SALVAGE GEAR.—If available, give the type and radius of action. If there are tugs, diving gear, etc., a general statement should include that information.

SEAPLANE LANDING AREAS.—In some harbors certain areas are reserved for seaplane landing. The use of these areas by shipping is restricted. This should be described in the Coast Pilot according to the importance of the area and the permanence of the regulations. (See Landing fields.)

SEAPLANE RUNWAYS.—Obtain location of them and note facilities, such as gas for launches, supplies, etc. Publish any special rules or regulations of a permanent nature affecting navigation. Usually a caution note will be sufficient.

SHOALS.—The term *shoal* should be limited to a detached area which constitutes a danger to surface navigation. A detached area whose least depth is such that it is not a danger to navigation should be called a *bank*. (See also **1682**.)

A series or group of shoals should be considered together; the description should be generalized, avoiding specific mention of each shoal spot unless there is a very definite reason for it. Isolated shoals, the outer part of a general shoal area, or an especially dangerous part may be considered among the exceptions. In describing shoals, there is no need to repeat information clearly shown on the charts, except to mention it in a general manner or as a caution to the navigator. Describe light effects, if any. Describe local phenomena, such as *jellyfish* shoals. (See Kelp.)

SHORE.—The term *shore* refers to the narrow zone of land fronting any body of water, except rivers. Describe, giving characteristics, such as height, color, wooded, sandy, cultivated, bold. Also give the appearance from seaward of land, points, islands, and rocks. This kind of information should be very carefully evaluated as to its value to the navigator and should not be given unless it has such value.

SIGNALS, SPECIAL.—This refers to such signals as those for a doctor, a fireboat, police, etc. Where these are used, describe them.

SILENT ZONES.—(See Fog signals.)

SOUND REFLECTION.—Note and describe any places where this may be used to advantage in navigation.

SOUNDINGS.—Describe the character of the slope of the bottom and whether soundings can be depended on to warn of the approach to danger or to enter ports in thick weather. Note any special submarine features, such as valleys, escarpments, etc., that may be useful as submarine landmarks. Off points and headlands note danger curve or sharply defined depth curves that are of value in rounding such features. Where the character of bottom is of value to navigators, describe in as much detail as necessary.

STANDARDIZATION.—So far as possible the methods used in writing the Coast Pilots should be standardized. Much time can be saved both in revising the Pilots and in preparing Supplements, if all the Pilots are written in the same manner, as outlined.

STARBOARD.—(See Port and starboard.)

STEAMER AND LAUNCH SERVICE.—In isolated regions, all information available about local steamer or launch service should be given. Describe the kind, whether passenger, automobile, freight only, or combined. Any variation in service in the different seasons of the year must be included.

STORAGE.—If available, state the kind, whether covered, open, general, or cold. Are there bonded warehouses? If small-boat storage space is available, give the size of the largest boat handled.

STORM WARNING DISPLAY STATIONS.—List in appendix, and also note in place in text. State whether there are day and night displays and if small-craft warnings are displayed.

STYLE MANUAL.—This is issued by the Government Printing Office, and contains rules of that Office governing the preparation of manuscript, and the correction of proof. Many examples of compounding, phrasing, abbreviations, etc., are given and the writer should familiarize himself with it and use it as a reference book.

SUBMARINE BELLS.—Note and refer to Light List for details.

SYMBOLS—Use the Symbols and Abbreviations chart published by the Bureau (see fig. 189).

TABLE OF CONTENTS.—The writer will find it advantageous to prepare a table of contents with chart numbers, chapter by chapter, before writing the different chapters.

Where the chart diagram is at all complicated, the areas covered by the largest-scale charts should be outlined in colors on a copy of the small-scale chart which is the subject of the chapter.

TABLES.—All tables, except for Directions and sometimes for bridges, should be in the appendix. (See Appendix in **9135**B(5).) In one of the Field Record Books a definite section should be set aside for the assemblage of tables for the appendix. So far as possible, the tables are to be prepared in the Office, and verified in the field.

In the manuscript, each table must be shown on a separate sheet without any of the text appearing on the sheet. This is a requirement of the Government Printing Office.

TIDES AND CURRENTS.—Practically all the information relative to tides and currents is furnished by the Division of Tides and Currents. All additional information obtained in the field should be referred to that division for approval before publication.

Information on tides and currents already published on charts and in tide and current publications should not be repeated in detail in the Coast Pilot. References to these publications are important. If information is of special value, a general statement should be made. Peculiarities and irregularities of tides and currents should be described.

If the port or place being described is one of the standard ports for which daily predictions are made in the Tide Tables or Current Tables, that fact should be explained in the Pilot. If there are special publications by the U. S. Coast and Geodetic Survey, such as books or current charts, dealing with tides and currents at any locality, they should be described in the Pilot.

In shoal areas, especially in enclosed waters, give the variation of surface level due to storms and, if possible, develop a relationship between velocity and direction of wind and the magnitude of resulting changes in surface elevation.

Times of change of current, etc., should be referred to the time of high or low water at a port for which tides are predicted in the Tide Tables, because the reader is apt to be more familiar with tidal data.

In discussing tidal currents, use the expression "current" rather than "stream." In describing currents, consider carefully expressions such as "flood current," and "north-flowing current," and use the one that best and most clearly defines the condition.

Give velocity, direction, duration, and the relation of time of slack current to that of high or low water. Note directions of currents with reference to axes of channels and openings through bridges and at other contractions of the fairway, across bars, in entrances, and in approaching docks and piers. Also note the occurrence of rips, swirls, and eddies, and the effect of wind and freshets on currents, and if flood or ebb current is ever entirely overcome. Describe fully all abnormalties in currents or marked variations from usual phenomena. The notes should cover the entire area, both inshore and offshore, and include all horizontal movements of surface waters, whether tidal, nontidal, or both. Where the currents are due to winds or other meteorologic cause, or are greatly modified in velocity, direction, and duration thereby, the variations produced should be determined and, if possible, their relation to the conditions that produce them given—for example, the relationship between the velocity and direction of the wind and the velocity of the current.

A general discussion of the wind currents on both Coasts is given in Chapter 1 of the Pilot, which is standardized. Local wind currents may be described in the text under local headings. A discussion of offshore currents and general coastwise currents in the area covered by the Pilot should be included in Chapter 2.

All current velocities should be expressed in knots.

TIDE RIPS.—Give location and limits, and conditions of tide, wind, and sea which cause them or make them worse. Give warning if they are dangerous under certain conditions and define these conditions. If it is possible to avoid them, describe how to do so.

TIME SIGNALS.—These are described in sufficient detail in Chapter 1 of the Pilot. Any places displaying visual time signals should be noted in the text.

TRUCKS.—If there is no railroad siding on the wharf, state if trucks can be used. Give facilities for handling freight, and whether it is hauled by truck to and from port. If fuel can be delivered by oil truck and put on board vessels, give quantity available, and rate of bunkering.

TRUE COURSES AND BEARINGS.—Only true courses and bearings are to be given. (See Bearings and courses.)

TOWBOATS AND WRECKING EQUIPMENT.—State whether towboats are available and if they are used for docking or mooring vessels. In the text and in Chapter 2 of the Pilot under a paragraph headed "Towboats and Wrecking Equipment," so that both items will be indexed, give the ports at which towboats and wrecking equipment are available, including such items as horsepower of towboats and the kind of wrecking equipment available at the different places. If this equipment is available at a number of ports in the region, it may be tabulated in the appendix, with references in Chapter 2 and in the text.

TWO-WAY COURSES.—In areas where traffic is congested, it may be desirable to recommend two routes in the Directions, one for entering, and one for leaving. Part of the Directions for New York and for Boston are now in this form. Before recommending two-way courses for other places, study carefully the information available, and obtain the approval of higher authority.

UNCERTAINTIES.—Where there is uncertainty regarding the correctness of statements obtained in interviews, they should be forwarded to the Office with an explanation and an estimate of their value. If considered worth while by the Office, such information may be entered in the Pilot as a report rather than as a fact.

WATER.—Give the following information on this subject: whether it is suitable for boiler use, and for drinking; piped to wharves and floats, or delivered by water boats; quantity available. Give the maximum rate at which water can be delivered to vessels. Give the upstream limit of salt water at different seasons or under various conditions. State whether overboard water is sufficiently fresh for drinking or for boilers and if it is used for these purposes.

WEATHER.—Obtain information in the field on any local peculiarities of weather that may be important, and include in Pilot if worth while.

Chapter 2 should contain a description of the weather and weather abnormalities which may be found in the region covered by the Coast Pilot.

WHARVES.—The depths at different wharves in the principal ports are given in the U. S. Corps of Engineers Port Series. The accommodations at such ports must be mentioned in the Pilot, but the descriptions can be more generalized if they are described in the Port Series. In any case, the maximum draft that can be accommodated at a port, and the depths at those wharves and floats used by the public must be given. Detailed information of this kind that is readily available elsewhere should not be included in the Pilot.

Descriptions of the wharves at many small ports, and the depths alongside, are published only in the Pilot. It is important to get such depths, reduce them to the sounding datum, and publish

them as "The depth at (*such a*) wharf was (*so many*) feet in (*July 1940*)." Also give length of available berths, storage, and transportation facilities, cargo-handling gear, fueling facilities, information about supplies, power connection, water, etc.

The Pilot must be written primarily for the convenience of the majority of its users. If the region is an isolated one frequented only by small craft, such as those used by fishermen and yachtsmen, more detailed descriptions of wharves, floats, and facilities for such craft must be included than would be required for a well-developed section where the existence of these facilities may sometimes be assumed.

Regardless of source, the date of the information must be considered, and if the information is of a changeable type, it must be of recent date or be checked.

If a wharf is reported to be dilapidated or in ruins, consider the advisability of giving the date if there appears to be a chance of repairs being made. It is important to note old piling that may be a menace to navigation.

WINDS.—Express in nautical miles per hour, and points true, or give force by Beaufort scale.

WRECKS.—Information regarding the occurrence of wrecks is often of value. Inquiries must be made, and the cases investigated to determine the various causes contributing in any way to marine disasters, such as little-known currents, inadequacy of aids to navigation, misleading or deceptive bottom relief in approaches, shifting shoals and channels, imperfect or inadequate charts. In general, the subject of wrecks can be treated in Chapter 2 of the Pilot to very good advantage, although mention should be made at the proper places in the text where there appear to be an unusual number of wrecks, indicating that there are unusual dangers. If there is a natural reason for wrecks in any locality, explain it, and state how to avoid those conditions.

Wrecks that are of importance to the navigator, either as dangers or landmarks, should be described in as much detail as warranted. Do not describe those that will be removed before the Pilot is published.

### 917. NOMENCLATURE AND TERMINOLOGY

*Abbreviations.*—Abbreviations must agree with those in use on the charts (see Symbols and Abbreviations chart, fig. 189). For further reference, use the Government Style Manual. In case of uncertainty, comply with the rules given in the latest edition of the "American Standard Abbreviations for Scientific and Engineering Terms," Pamphlet No. *ASA.Z*10.1–1941 (Library No. 503 *A* 51).

*Capitalization, compounding, and punctuation.*—In general, the rules given in the Style Manual may be accepted as final authority, but in some cases, Webster's New International Dictionary, and other authorities must be considered.

*Definitions.*—"A Glossary of Sea Terms," by G. Bradford, is a reliable reference work.

*Terminology.*—The following terminology is in use in the Coast Pilot Section in 1942. Capitals and lower-case letters are used as in the examples. Obviously such a list cannot be complete, but the correct usage with respect to terms not included can be determined by analogy.

boulder
breakwater; Georgetown breakwater; Georgetown Harbor breakwater
bridge; Brooklyn Bridge; the Pennsylvania Railroad bridge
buildings; a building; Whitehall Building
buoys:
- bell buoy
- black buoy
- fairway buoy
- Gedney Channel bell buoy
- Gedney Channel lighted buoys
- gong buoy
- horizontal-banded buoy

buoys—continued.
- lighted bell buoy
- lighted buoy
- lighted gong buoy
- lighted whistle buoy
- lighted trumpet buoy
- red buoy
- trumpet buoy
- vertical-striped buoy
- whistle buoy

church; a church; St. Philips Church; St. Phillips Church spire
close to (hyphenate only when used as an adverb)

close aboard
Coast Guard
Coast Guard station
coastline
coastwise
curve
customhouse; Charleston Customhouse
daymark
deep-draft vessels
deep-sea
dock; the dock; but National Docks
extremity
factory; a factory; but Commonwealth Shoe Factory
fairway
flagstaff
foghorn
fog signal; Point Reyes fog-signal station
heave-to
high water (hyphenate only when used as an adjective)
hotel; or the hotel; St. Margaret Hotel
ingoing
inshore
International Code
jetty (see breakwater)
keep a sharp lookout, but look out for the buoy
leadline
lee shore
leeward
lifeboat
lifesaving station (in text); but U. S. Coast Guard Lifeboat Station
light; the light; Owls Head Light
lighthouse; the lighthouse
lightship; the lightship; Ambrose Lightship
low water (hyphenate only when used as an adjective)
marine railway
masthead
mean high or mean low water—MHW or MLW (no spaces)
mid-bay; mid-channel; mid-river; midstream; midway
molehead
naval vessel
navy yard (capitalize if specific navy yard is meant)
nearby
north or northern, etc. (as adjective)
northward, etc. (as adverb)
off-lying
offshore
pier; the pier; pier B; Commonwealth pier
pierhead
pierhead line
pilothouse
pilot vessel
point; the point; Point Blunt; Montauk Point
quarantine station
radiobeacon
radio direction finder
radiogram
radiophone
radiotelegram
radiotelegraph
radiotelephone
R.A.R.
r. p. m.
railroad
range lights
sandbank
shipboard
shipyard; Lawley Shipyard
shoreline
stack (use rather than chimney)
Standard Oil Co.
steamer
steep-to
Submarine Operating Area
tidal bench mark
tide station
topmark
towboat; water boat; pilot boat
upturned
vessel; steamer; sailing vessel; small craft (and boats); (to be used instead of ship, bark, schooner, boat)
waterfall
water tank
weather-bound
weather shore
wharf; a wharf; Tillson wharf
windward
wire drag; (hyphenate only when used as an adjective)

## 92. PROCESSING OFFICES

Processing Offices are established from time to time, and maintained, at selected coastal cities conveniently located to project areas or to home ports of survey ships. The Processing Offices are for the purpose of processing, in an orderly and systematic manner, field records of surveys accomplished from vessels, where there is no opportunity to complete the office work on board ship. The offices are under the direct authority of the Director. In matters pertaining to the survey work, however, a

Processing Office may be under the general supervision of the senior Commanding Officer in the area or, if at a city which is a district headquarters, may be under the general supervision of the District Supervisor.

### 921. Personnel at Processing Offices

*a. Officer-in-charge.*—The officer-in-charge is assigned by the Director, usually for a period not to exceed 1 year. So far as practicable the officer is selected, upon recommendation of the Chiefs of Party whose records are to be processed, from those who have been employed during the preceding season on the field work of one of the survey ships, the work of which is to be processed at the office. The officer-in-charge at some Processing Offices acts as Chief of Party and handles all accounts of his office, including payment of personnel, rent of office space, and miscellaneous expenditures.

The officer-in-charge shall be directly responsible for the maintenance and operation of his office. He is in immediate charge of all personnel assigned to the office, all general property and instrumental equipment, and all records and data transferred to him for processing, and is responsible for the care and upkeep of the quarters occupied.

*b. Additional officer personnel.*—When practicable, additional officers are temporarily assigned between field seasons—one officer from each of the survey ships, whose records are to be processed at the office, except the ship from which the officer-in-charge is transferred.

The officer next junior in rank to the officer-in-charge acts as assistant to the officer-in-charge in the conduct of the Processing Office and is in charge during his absence.

*c. Civil service personnel.*—Civil service personnel employed at the Processing Office are appointed by the Secretary of Commerce upon recommendation of the Director. They shall be employed, under supervision of the officer-in-charge, on drafting, computation, preparation of correspondence, reports, accounts, and other duties connected with the work of the offices, and will be responsible to the officer-in-charge for the efficient prosecution of the duties assigned.

### 922. Transfer of Records

Records of field work to be processed shall be transferred to a Processing Office by chiefs of field parties under authority from the Director. Receipt of the records should be acknowledged by the officer-in-charge on Form 413, Letter Transmitting Field Records, the original copy being forwarded to the Chief of Party concerned and a duplicate copy being forwarded to the Director. After receipt by the officer-in-charge, that officer shall be responsible for the safekeeping of the records until they are returned to the Chief of Party or forwarded to the Washington Office.

Copies of letters transmitting records to the Washington Office shall be forwarded by the Processing Office to the Chief of Party who accomplished the field work.

Chiefs of Party, whose surveys are to be processed, shall forward the records promptly during the season as the field work and the preliminary office work are completed, in order to establish and maintain a regular flow of work to the Processing Office.

Likewise, surveys on which the office work has been completed at Processing Offices shall be forwarded promptly to the Washington Office, or to the Chief of Party concerned for his inspection, in order to maintain a steady and regular flow of sheets to the

Washington Office. The practice of retaining survey records, especially topographic survey sheets, long after they have been completed cannot be tolerated.

## 923. Preliminary Office Work by Field Parties

The function of a Processing Office is to complete such office work on the field records as the regular personnel of the survey party is not able to complete, owing to lack of time or personnel. In general, all preliminary work of a nature requiring special experience or special familiarity with the particular field operations shall be performed by the field party. Maximum efficiency will be obtained if the work transferred to the Processing Office is of a general routine nature. To this end Chiefs of Party shall make every effort to complete at least the following office work before transmitting field records to a Processing Office. These requirements, however, should not be considered as preventing a Chief of Party from completing as much more of the office work as time and personnel permit.

### *9231. Hydrographic Surveys*

*a. Sounding Records.*—The Sounding Records shall be examined thoroughly to ensure that the record of the field work is clear and complete (see **3257** and **818**). All corrections to soundings, such as tide reducers, velocity corrections to echo soundings, and corrections to compensate for an error in the apparatus, shall be entered and *checked* (see **822**); but the soundings need not be reduced.

*b. Boat sheet.*—The boat sheet shall be examined thoroughly to ensure that it is complete, that all essential notations are clear and that nonessential notations have been deleted (see **3257**).

*c. Bomb Records.*—The velocity of sound for each R.A.R. distance shall be entered and checked. The R.A.R. distances need not be reduced to plotting distances. (See **8311**.)

*d. Buoy positions.*—All traverses, astronomic sights, and other data to locate buoys shall be computed, adjusted, and checked, and a list of final buoy positions shall be furnished, except for buoys located solely by cuts, whose positions are to be determined by plotting on the smooth sheet. (See **832** and **8435**.)

*e. Special reports.*—All reports on special subjects, such as echo soundings, velocity of sound, buoy control, Radio Acoustic Ranging, and taut-wire sun-azimuth traverses, shall be prepared. (See **832** and **833**.)

*f. Miscellaneous.*—Each survey shall be accompanied by notes for Descriptive Report (**385**), including statistics (**8431**), and a memorandum listing office work that has been done on the survey by the field party and the work remaining to be done at the Processing Office. In this memorandum attention should be directed to phases of the office work that are not of a routine nature, or in which special difficulty may be expected, and all available information should be included that may be of value in processing the records.

### *9232. Topographic Surveys*

*a. Inking.*—The shoreline, station symbols, and all off-lying features shall be inked. Appropriate notations shall be added lightly in pencil to guide in inking any features that require special care, or to explain any features that might be misinterpreted.

*b. Descriptive Report.*—The Descriptive Report shall be prepared and submitted in final form and approved.

### *9233. Triangulation*

The triangulation record books and triangle closures shall be checked, and preliminary lists of directions prepared and checked. A rough sketch of the scheme, complete and to scale, shall be furnished, supplemented by clarifying notes where necessary. Descriptions of stations and recovery notes shall be prepared, at least in pencil, making certain that all distances and directions to reference marks are included.

### *9234. Tide and Current Records*

Unless otherwise instructed, chiefs of field parties shall forward all tidal data and records of current observations directly to the Washington Office. As tide reducers will ordinarily be entered in the Sounding Records and checked by the field parties, no tide records will be required by the Processing Office.

### *9235. Miscellaneous Records*

A copy of the season's progress sketch, and the sheet layout if available, shall be furnished to the Processing Office.

Miscellaneous data not having a direct relation to the hydrographic and topographic surveys, such as magnetic observations and the like, should be processed by the field party and forwarded directly to the Washington Office.

## 924. Completion Work by Processing Offices

Field records will ordinarily be transferred to a Processing Office by chiefs of field parties after all preliminary work has been completed. The Processing Office shall continue the office work to the extent usually required of field parties before transmitting the records to the Washington Office. In general, work to be performed by the Processing Office will include the following steps.

### *9241. Hydrographic Surveys*

(*a*) The reduction and checking of the soundings in the Sounding Records.

(*b*) The construction and inking of smooth-sheet projections, and the plotting and inking of the control stations.

(*c*) Plotting the positions of the soundings—the three-point fix and R.A.R. positions.

(*d*) *Penciling* the soundings.

(*e*) Drawing the depth curves *in pencil.*

(*f*) Lettering the geographic names *in pencil.*

(*g*) The preparation of the title sheet (Form 537).

(*h*) The completion and writing of the Descriptive Report.

### *9242. Topographic Surveys*

(*a*) Inking the projection, inshore details, vegetation, and other details not already inked.

(*b*) Lettering the geographic names *in pencil.*

(*c*) The preparation of the title sheet (Form 537*a*).

#### *9243. Triangulation*

(*a*) The preparation of typed copies of the lists of directions furnished by the field party.

(*b*) The computation of triangles and positions.

(*c*) The preparation of typed lists of geographic positions.

(*d*) The preparation of a sketch of the scheme.

(*e*) The preparation of typed copies of the descriptions of stations and recovery notes, from notes furnished by the field party.

(*f*) The preparation of a report on the triangulation.

#### *9244. Miscellaneous Work*

When specifically authorized by the Director, or when the officer-in-charge shall determine it to be practicable without interfering with the processing work of the office, boat-sheet projections may be prepared at the request of a Chief of Party.

### 925. Inspection of Office Work by Chief of Field Party

Completed hydrographic smooth sheets with their Descriptive Reports may be forwarded by the Processing Office to a Chief of Party for his inspection when so requested by that officer, or when the officer-in-charge of the Processing Office deems it advisable to call some questionable features to the attention of the Chief of Party. If further office work on a survey is considered desirable by the Chief of Party, the sheet and Descriptive Report shall be returned to the Processing Office. Otherwise, the sheet and Descriptive Report shall be forwarded to the Washington Office by the Chief of Party, and a copy of the transmitting letter shall be furnished to the Processing Office. When a sheet has been inspected and approved by the Chief of Party, he shall indicate this fact in the Descriptive Report (see **8437**).

### 926. Accounts, Reports, and Correspondence

*a. Accounts.*—For Processing Offices at cities which are district headquarters, the District Supervisor shall make all disbursements. The accounts of the Processing Offices shall be kept separate, and a separate statement of allotment balances shall be submitted for the Processing Office. For other Processing Offices, and when specifically so instructed by the Director, the officer-in-charge shall be bonded as a Chief of Party and as such, shall handle all accounts of his office in accordance with the Regulations and instructions from the Washington Office.

*b. Progress reports.*—Reports of progress on office work shall be submitted on the first of each month to the Washington Office, using Forms *M*–961, *M*–962, and *M*–963 in accordance with **8514** and the instructions at the bottom of each form. Duplicate copies of these forms shall be forwarded to the District Supervisor or the Commanding Officer under whose general supervision the office operates.

*c. Correspondence.*—In all matters pertaining to personnel and the general work or policies of the Processing Office, the officer-in-charge shall correspond directly with and receive instructions from the Director. Copies of all such correspondence originating at a Processing Office shall be forwarded to the District Supervisor or the Commanding Officer supervising the office work on surveys. On matters pertaining to specific surveys and records, the officer-in-charge shall correspond directly with and receive instructions from the Chief of Party concerned, or with the officer who made the

survey. Ordinarily, copies of such correspondence need not be forwarded to the Washington Office nor to the District Supervisor.

## 93. HYDROGRAPHIC SURVEYS AT THE WASHINGTON OFFICE

### 931. Receipt and Registry

The Surveys Branch of the Division of Charts is the custodian of all hydrographic survey sheets and Descriptive Reports. All Sounding Records, Bomb Records, and miscellaneous hydrographic data are in the custody of the Library and Archives.

All data from the field are received in the Library, where each item is checked against the transmitting letter (Form 413) and stamped with the Bureau property stamp. Receipt is acknowledged by the Chief Clerk of the Bureau. All the data are then forwarded to the Surveys Branch where each survey is assigned a registry number (**1542**) and is recorded in the register of surveys. This registry number is stamped on the hydrographic sheet, Descriptive Report, Sounding Records, Bomb Records, and all other miscellaneous records and reports pertaining to the survey. The Sounding Records, Bomb Records, and other miscellaneous data are then returned to the Library, where they are given accession numbers and are classified and recorded.

The Sounding Records are then forwarded to the Division of Tides and Currents for verification of the tidal plane of reference (sounding datum) (see **9323**).

All hydrographic smooth sheets and original topographic survey sheets are stored in a fireproof vault conveniently located in the Surveys Branch. Adjacent to the vault, there is maintained a file of charts, known as *diagrams*, on which the limits of the surveys are outlined. Every survey ever made by the Bureau is indicated on these chart diagrams. This file of charts serves as an index by area of the surveys.

As soon as a hydrographic survey is received by the Surveys Branch, its area is diagrammed on the proper chart diagram.

At the time the survey is diagrammed, a check is made to see whether the data listed on the last page of the text of the Descriptive Report (**842***Z*) have been received in the Office. A statistics sheet (**844***a*) on which are listed the number of Sounding Records, Bomb Records, etc., is inserted in the Descriptive Report. The Descriptive Report is examined by the Chief of the Surveys Branch, the Immediate Attention Memorandum (Form *M*–238) is inserted, and the Descriptive Report is forwarded to other officials in the Office for immediate attention to any pertinent information contained therein.

### 932. Miscellaneous Operations

#### *9321. Verification of Geographic Names*

A complete set of nautical charts of late date is maintained in the Surveys Branch as a standard of geographic names. All names for which the U. S. Board on Geographical Names (see **167**) has rendered decisions are identified on these charts, and as other names are investigated in connection with the survey sheets they are approved on these standards for charting.

A permanent and complete record of the investigation of the geographic names is maintained on Form *A*–712, filed by area. Each copy of the form is for the names in an area of 6 minutes of latitude by 6 minutes of longitude. Each named feature is identified by latitude and longitude, and the sources on which the name appears are listed, such as the surveys and charts of the Bureau by number, the Coast Pilots.

the Light Lists, and other federal surveys and maps. Decisions of the U. S. Board on Geographical Names are identified, and any alternate names found are listed.

The geographic name list included in the Descriptive Report (see **8433**) of each hydrographic survey is checked against the set of chart standards and all names on the list, whose spelling and application are exactly identical with the standard are at once approved for inking. All others are investigated before approval, use being made of the special report on geographic names submitted by the field party (see **163** and **856**); or they may have to be submitted to the U. S. Board on Geographical Names for decisions.

### *9322. Title and Geographic Names Inked*

All names which have been approved on the geographic name list attached to the Descriptive Report, are inked in black on the smooth sheet by one person assigned to that work, using a mechanical lettering set. At the same time the title is inked on the hydrographic sheet, from information on the Title Sheet (**8412**), using a standard form and template. The result of this procedure is that the prominent lettering on all sheets is of equal quality and appearance.

All names applied to hydrographic features are inked in slanting letters and those applied to topographic features in vertical letters. Sizes of lettering are determined by the relative importance of the features named. Where convenient, the names are placed on the sheet as they appear on the chart, except that names are kept out of the sounded area so far as possible. Any names which must be placed in the sounded area are left in pencil until after the soundings have been inked. All names are inked to be read from the south and as many as possible are lettered parallel to the lines of latitude. Those which cannot be lettered in a straight line are lettered along a compound curve—never a reverse curve. (See also **787**.)

### *9323. Verification of the Sounding Datum*

On receipt of the Sounding Records from the Library, the Division of Tides and Currents checks the plane of reference for each tide station used in the reduction of soundings. If the survey party, in reducing the soundings, has used a preliminary plane of reference differing by more than 0.3 foot from the final adopted plane, a new reduction of the soundings is made. If the plane used is found to be correct within the defined limits, only a selected few of the reducers entered in each day's work are checked. The reduction of the soundings is not ordinarily checked in the Office.

Form 712, Tide Note for Hydrographic Sheet No______, is filled out and forwarded to the Surveys Branch for insertion in the Descriptive Report in place of the original tide note. (See **8432** and **844***c*.)

To indicate that the plane of reference has been verified, an approval stamp is impressed on the inside of the back cover of each volume of the Sounding Records.

## 933. Verification of Hydrographic Surveys

After a hydrographic survey has been received at the Washington Office, has been registered, and the various steps mentioned in **932** have been completed, it is verified and the soundings are inked by a cartographer.

The verification of a hydrographic survey consists of a thorough examination of the survey data as submitted from the field to ensure that all phases of the office work have been completed in accordance with chapter 7 of the Hydrographic Manual and

with any other specific instructions. Subsequently the soundings, bottom characteristics, and other details in the sounded area are inked and any deficiencies are supplied.

It is imperative that there be no duplication of work by the verifiers and reviewers (see **934**). The verifier's duties are with the present hydrographic survey and its accompanying records, and with correlating it to other contemporary surveys—the hydrographic surveys with which it makes a junction and the contemporary topographic or air photographic survey. When the verifier completes his work, the survey should be a complete and accurate record of all hydrographic information currently obtained in the area. The verifier must not consider the present survey in its relation to prior surveys in the same locality. That is the function of the reviewer (see **9343**). However, any matters pertaining to the review that are noted during the verification should be called to the attention of the reviewer on Form *M*–996.

While drafting of the quality found on charts is not required in inking hydrographic sheets there must be no sacrifice in accuracy of any important details on the sheet, nor in the legibility of the soundings (see **721**). Soundings particularly should be unmistakably legible and they should be inked in accordance with **773**. Notes pertaining to hydrographic features should be in slanting letters and those pertaining to topographic features in vertical letters (see **781**).

A verifier should be thoroughly familiar with chapters 3 and 7 of this Manual, where the requirements for field work and for the preparation of the smooth sheet are given in detail. In his verification he is to be guided by the instructions in **9331** to **9339** inclusive. No hydrographic smooth sheet is to be considered as verified until all requirements and instructions have been complied with insofar as practicable. The schedule of penciled and inked details in **792** may be used as a check list.

### *9331. Boat Sheet and Records*

The Descriptive Report should always be consulted before any work is done on the sheet, as it frequently contains vital information.

The boat sheet should be referred to constantly during the verification, particularly to check the accuracy of the protracting (see **767**). The boat sheet often contains supplemental details and helpful notes, some of which, after being edited, should be inked on the smooth sheet (see **3212**).

The Sounding Records contain no data that are not essential to the complete and accurate plotting of the survey. Every miscellaneous entry in the Record, especially in the "Remarks" column should be noted and checked with colored pencil. In many cases the only information available regarding rocks awash, which are often of supreme importance, is found in the "Remarks" column. Always consult higher authority in cases where the required action is not entirely clear. (See **815**.)

The original entries in the Sounding Records are always made in black pencil. Amendments in colored pencil by the person who plotted the sheet should be considered as a guide by the verifier but, as they are often made months after the date of the field work, the verifier should use independent judgment as to whether the amendments are justified. More weight should be given to amendments made by a member of the survey party.

The verifier should checkmark with colored pencil all positions that he verifies, using a different color from that found in the Records. He should use the same color for all notations that he makes in the Record.

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In general the verifier will not need to consult records such as dead-reckoning abstracts, astronomic data, and Bomb Records; or special reports on velocity of sound, Radio Acoustic Ranging, or taut-wire sun-azimuth traverses.

### *9332. Protracting*

The metal protractor should be checked before beginning work and at intervals of a month or so thereafter (see **4533**).

In checking protracting, consideration should be given to the quality of work on sheets previously verified, which were plotted by the same person or under the direction of the same officer-in-charge. Where these have been found to be uniformly accurate and carefully done, the amount of checking should be held to a minimum. With no guide to the probable accuracy, the verifier should begin by verifying approximately 10 percent of the positions and, after convincing himself that the general accuracy of the plotting is satisfactory, thereafter he should verify the protracting in the following cases only:

(*a*) Where positions differ appreciably from the boat sheet (see **7671**).

(*b*) Where the depths at crossings or along closely adjacent parallel lines differ (see **7771**).

(*c*) Where there is reason to suspect, when inking the soundings, that a position has been erroneously plotted (see **774**).

(*d*) All detached positions serving to locate critical soundings, rocks, or buoys (see **766**).

(*e*) Positions that cannot be reconciled with the time interval or course in the Sounding Record.

(*f*) Adjacent positions, where other checks fail to reveal the cause of an excessive difference in depths at a crossing of sounding lines.

In all cases the boat sheet should be compared with the smooth sheet. If the survey is not so complicated as to make it impracticable, a tracing of the sounding lines on the smooth sheet may be made and superimposed on the boat sheet to reveal any differences in protracting of the two sheets that should be verified.

Errors in plotted positions may be due to careless protracting or mistakes made by the person who plotted the smooth sheet, or they may be due to errors in the recorded data in the Sounding Record.

A metal protractor out of adjustment will result in errors in positions. This type of error can be detected by the approximate uniformity of the errors.

The three-point fix may be weak or almost indeterminate, as where the position lies on or near the circumference of the circle passing through the three stations (a revolver) (see **3332**).

Many of the errors which may occur in the recorded data are discussed in **3414**, **3416**, **7624A**, and **774**.

### *9333. Soundings and Bottom Characteristics*

The penciled soundings are to be considered as a guide only. Every sounding on the sheet shall be checked against the Sounding Record or the fathogram either at the time it is inked or afterwards. The cartographer must also pay particular heed to the spacing as indicated by the intervals between the recorded times of the soundings. The standard spacing dividers should always be used for this purpose. In spacing soundings the instructions in **7721** shall be followed.

Special attention should be given to the placing of soundings around turns (see **3454** and **7682**), to variations in the speed of the vessel (see **3351**, **3461**, and **7721**), and to variations in course between fixed positions (see **3352**, **3463**, and **7672**).

The character of the inked soundings shall be in accordance with the instructions in **773**. Soundings in fractions or decimals shall be in accordance with **7713** and **7714** and shall be inked in accordance with **7734**, but which fractional soundings are to be inked shall be decided at the time of verification. Minus soundings shall be inked in accordance with **7715** and **7735**. Special attention must be paid to ensure that the least depth is plotted on all shoals and dangers, and in accordance with **7753**.

Where all recorded soundings cannot, or need not, be plotted, and where soundings are taken from fathograms, selection shall be made in accordance with **7725** and **7726**. Where the soundings are from fathograms or where some of the soundings recorded in the Sounding Records are omitted in the inking, a notation should be included in the title on the sheet.

*a. Erroneous soundings.*—These may be due to errors in the recorded depths, errors in reducing the soundings, or the soundings may not be in their true positions. Owing to the fact that there is little opportunity to check the various field operations as they are performed, the verifier of the smooth sheet must watch for all abnormal soundings which may constitute errors. Examples are: depth curves out of harmony with others in the locality; bad crossings; shoal soundings where none should be expected; deep soundings in shoal areas.

The various causes of errors in recorded soundings are discussed in **774**. The reduction of all suspicious soundings should be checked. Soundings taken with an inclined leadline or wire are always too deep (see **3464**).

Discrepancies between the soundings of overlapping surveys, or where the area is distant from the tide gage, may be due to erroneous tidal planes. Such cases should be referred to the Division of Tides and Currents for re-examination. (See also **825**.)

*b. Bottom characteristics.*—Bottom characteristics shall always be inked, but it is not always necessary to ink all that are recorded, and a judicious selection is required. The bottom characteristics of outstanding shoals should always be shown. Where echo sounding has been used, it may be necessary to carry bottom characteristics forward from prior surveys (see **3842**). The symbols of part "O" of the Symbols and Abbreviations chart (fig. 189) shall be used, and shown in accordance with **3843** and **783**.

### *9334. Topography, Rocks, and Shoal Areas*

The shoreline should always be shown on inshore surveys. It is desirable, although not essential, to have the shoreline on offshore surveys. (See **751**.) Shoreline revised by the hydrographer or originating with the hydrographic survey should be inked in accordance with **753**.

Contemporary topographic surveys are the source of the shoreline, most of the control stations, and many of the rocks on hydrographic sheets. They should be examined for rocks, especially rocks awash, which may have been omitted or transferred in error. Such of these as appear authentic should be placed on the sheet. The topographic surveys are also the source for the low-water line where the hydrographic survey fails to define it with zero soundings. The air photographic surveys should also be examined when drawing low-water lines. The low-water line shall be inked in accordance with **754**.

Shoal areas that are covered at low water but that have not been sounded should be outlined with a black dash line and appropriately marked. These occur infrequently.

*a. Symbolization of rocks.*—Rocks shall be symbolized on hydrographic sheets in accordance with **7823**, reefs and ledges in accordance with **7824**, and other rocky areas in accordance with **7826**, and the elevations and notes accompanying them shall be according to **7825**. Adjustments between topographic and hydrographic data shall be made in accordance with **7827**.

Without exception, where a sounding, surrounded by deeper water, reduces to zero and the notation in the Records is "rky" or "on rock," the rock awash symbol (✳) shall be used (see **7823*b***). For emphasis, a rock constituting a menace to navigation may be symbolized by the rock awash symbol and accompanied by the notation "awash at extreme low tides", even though not in accordance with **7823**.

The correct notation for a rocky bottom is "rky". Where the notation "Rk" or "Rock," has been used in the Sounding Record, it should be interpreted as meaning "*rky*", unless the surrounding depths are much greater than the sounding in question or a special explanation is placed in the "Remarks" column, in which case "*Rk*" is to be appended to the sounding.

Where a cluster of rocks awash is contiguous to the shoreline and descriptive notes are given for each rock, only those notes shall be inked that give the elevations of the outermost rock and of the highest rock. Where the reef is a detached one, consisting of numerous detached rocks, or is continuous in character, the highest rock or point of the reef should be described as well as such other rocks or points as the importance and extent of the feature justify.

The range of tide given in the report of the Division of Tides and Currents shall be examined before being used to determine the heights of rocks, to make certain that it is based on MHW (and not on MHHW).

## *9335. Adjoining Surveys*

Where two surveys join or overlap, the soundings at the junction shall be transferred from one of the hydrographic sheets to the other. The purposes of the transfer are: (*a*) To permit a comparison to be made between the depths at the junctions. Where different methods, such as echo sounding and leadline sounding or three-point sextant fixes and R.A.R. control, are used on two adjoining surveys, a defect in one of the methods is strikingly disclosed from a study of the overlap. It also permits a junction of the depth curves on the two surveys. (*b*) To insure that no *holidays* have been left in the hydrography at the junctions. (*c*) To simplify chart construction.

In effecting the transfers, the following practices shall be followed:

In general, overlap shall be transferred from the smaller scale to the larger scale (e.g., from 1:40,000 to 1:20,000). This usually means the transfer of fewer soundings.

In changeable areas, only hydrography from surveys of the same, the following, or the preceding year, shall be transferred.

In unchangeable areas, contemporary surveys should always be transferred. Where there is no contemporary survey, hydrography from prior surveys shall not be transferred except where the new survey is a resumption of a previous project, or where the project instructions specify that a satisfactory junction shall be made with a prior survey. In such cases the latest survey should show whether such junction has been effected.

Soundings on a sheet must not be obscured by soundings transferred from an adjoining sheet. If a transferred sounding falls too close to a sounding already on the sheet, omit the former unless it is an important shoal sounding, in which case it should be shown and the less important sounding

omitted. In general the cartographer should be guided in omitting overlapping soundings by the same rules as when inking soundings on coinciding or closely spaced adjacent lines.

Do not transfer bottom characteristics from an overlapping sheet, unless the latter is to be superseded.

Where comparative soundings occur within the overlapping area, transfer only one of each pair of soundings. It is immaterial which one is transferred, but if it is the vertical cast, omit the letters "VC".

Transferred soundings should always be in color. Red, blue, and green are the preferred colors. It is permissible to use the same color for overlaps from two different sheets provided the sheets are not contiguous. For example, red can be used for overlap at the top and bottom of a sheet.

The notation "JOINS H–----" should always be placed just outside the limits of the hydrography and in the same color as the transferred soundings. A similar notation should be placed on the sheet from which the overlap was taken. Where adjoining surveys have been registered but not verified, such notations should be made in pencil. These notations should be made with the Leroy lettering set, using No. 100 template (slanting letters).

Soundings from overlapping sheets are to be shown only to just outside of the limiting line of soundings on the principal sheet. Where no actual overlap exists between the two sheets, only the nearest line of soundings need be transferred.

Where the scales of the two adjoining sheets are the same, soundings are to be transferred by the tracing-paper method. Where the scales are different and the lines regular, proportional dividers, or a projector, should be used for making the transfer. The ends of straight portions of lines can be transferred by proportional dividers and intermediate soundings filled in with the spacing dividers either from the sheet proper or from the Sounding Records. Where the lines are irregular a projector shall be used, or a photostat of that portion of the sheet should be made to the desired scale and the soundings transferred by the tracing-paper method.

Where an enlargement of more than twice needs to be made, the overlapping soundings should be plotted directly on the sheet if the control is available. Otherwise the enlargement should be made by projector, by photography, or by proportional dividers, whichever is more economic, great care being taken in such cases when using the latter method.

Wherever overlap is transferred, the curves on the two sheets should be made identical in the overlap.

Where a sheet is surrounded by a number of sheets, always show all overlaps on one sheet, where possible to do so. Where the scale is the same on overlapping sheets the overlap should be placed on the inshore sheet.

### *9336. Depth Curves*

The depth curves shall be drawn lightly in pencil by the verifier in accordance with **7762** and, after they have been approved, they shall be inked in the standard colors given in table 27 in accordance with **7763.** In general, all applicable curves given in the table shall be inked, except those marked "omit," which are only to be used where needed to delineate submarine relief that might otherwise be overlooked. All curves not inked shall be erased. (See also **9342*b*.**)

### *9337. Confidential Sheets and Records*

Survey sheets and records of a confidential nature are plainly stamped "Confidential" when they are received at the Washington Office. They are kept in locked compartments in the vault in the Division of Charts and are removed therefrom only on approval of the Chief or Assistant Chief of the Division of Charts. They must be replaced in the locked compartments each evening before the close of the day's work. Insofar as practicable any work requiring their use shall be completed within one working day.

Confidential sheets and records are to be reproduced only as approved by the Chief or Assistant Chief of the Division of Charts. Negatives made in reproduction shall be destroyed immediately afterward. Reproduction copies sent out of the Office are to

be dispatched either by registered mail or by special messenger (see **125**). The file copy of the transmitting letter shall state the method of forwarding.

### *9338. Miscellaneous*

All aids to navigation should appear on the hydrographic sheet. The cartographer should see that all located by triangulation or topography or appearing on contemporary hydrographic or wire-drag surveys are plotted or transferred.

The cartographer verifying the survey should supply such deficiencies as can be done in the Office. Certain steps in the construction and field plotting of smooth sheets are required to be checked (see **746**). If there is no evidence that this has been done in the field, it shall be done by the verifier.

The instructions of the Hydrographic Manual specify that corrections for reducing soundings shall be entered to closer limits under certain conditions (see **8143** and **822**) and the verifier shall verify that this requirement has been complied with.

Pencil notations and temporary marks of all kinds, except place names, on registered hydrographic and topographic survey sheets, must be removed by the cartographer before the sheet leaves his custody. Temporary notations are necessary in some phases of the verification and review of a survey, but these must be removed before the sheet is returned to the files. If a temporary record is necessary, such record should be made as a note on an attached sheet of paper or on a tracing of a section of the sheet. Although the registered air photographic survey is a photolithographic copy, it is the registered copy and should be treated with the same care as other original sheets. Copies of these, printed on chart paper, may be obtained from the Distribution Branch, on which any required notations may be made.

### *9339. Written Report*

The verifier shall prepare a critical report on the survey, using Form *M*-996, Verifier's Report of Hydrographic Survey No. H– . . . , for this purpose. This form provides a check list to ensure that the verifier omits no phase of his work, and provides space for comments as to the quality of the field work and office work on the survey, and space for calling the reviewer's attention to any facts about which he should be informed.

All written references to registered hydrographic or topographic surveys shall include the year of the survey in addition to the registry number, thus: H–3574 (1907). (See **1543**.)

The written report is primarily for the use of the reviewer. Such comments as he believes are of permanent value shall be included in the written review, after which the verifier's report is removed from the Descriptive Report.

The Office statistics shall be prepared on Form *M*-1683-1 and added to the Descriptive Report. This includes the names of the verifier and reviewer, the time spent by each in his verification and review, and indicates by certain statistics the amount of revision that had to be made to the sheet during verification. (See **844**.)

## 934. REVIEW OF HYDROGRAPHIC SURVEYS

The purpose of verification is to verify certain phases of the office work done on hydrographic survey sheets in the field or at a Processing Office and to correlate contemporary survey records of the Coast and Geodetic Survey and ink the sheet as a complete contemporary record.

The purpose of the review is to extend this correlation into the past and more broadly into the present and future, and generally to consider the survey in its broader aspects insofar as its application to the charts is concerned. The survey is compared with every prior survey (hydrographic, topographic, and wire-drag) made by the Bureau covering the same area, and with charted data that have originated from other sources.

The aim of the review is to make the survey complete with reference to all information on prior survey sheets, so that it is unnecessary for the chart compiler to consult any prior surveys of the area covered, except as specifically mentioned in the written review.

The reviewer must be intimately familiar with conditions in different regions, and not only with present-day standards of accuracy and methods of surveying, but also with those of prior periods.

### *9341. Records, Reports, and Instructions*

Before beginning the review of a hydrographic survey, the reviewer should familiarize himself with the survey, the methods of field work used, the characteristics of the area, and the preceding office work. For this purpose he should first familiarize himself with the largest-scale chart of the area, and then read the following to see whether they contain data or information that might affect the general treatment of the sheet:

(*a*) The project instructions (see **121** and **842***A*).
(*b*) The Descriptive Report (see section **84**).
(*c*) The verifier's report (see **9339**).
(*d*) Special reports intimately connected with the survey (see **842***Z*).

### *9342. Inspection of the Work of the Verifier*

The reviewer should inspect generally the various phases of the office work done by the verifier, checking anything important that has not previously been checked, and examining critically any changes that the verifier may have made to ensure that they are justified. He should call to the verifier's attention any errors or deficiencies in the latter's work, and have the errors corrected and the deficiencies supplied. Particular attention should be given to the following:

*a. Differences of depths at crossings.*—The reviewer shall inspect the sheet for excessive differences at crossings that have not already been noted. Any found shall be investigated with a view to rectifying them and ascertaining the probable causes. (See **7771** and **842***K*.)

*b. Depth curves.*—The sheet should be examined for omitted depth curves or unnatural convolutions with a view to remedying them. In coastal waters and inside waters, where the bottom is generally flat or regular, intermediate curves of 3, 24, and 36 feet should sometimes be inked to emphasize features that would otherwise be unnoticed. In offshore coastal waters beyond the 20-fathom curve the standard curves shall always be inked (see table 27). Any nonstandard curves shall be inked in brown. (See also **7762** and **7763**.)

*c. Junctions.*—The reviewer should examine individually the various junctions with contemporary surveys and see that the soundings have been correctly transferred and verified, depth curves adjusted and inked, and proper junction notes made on the respective sheets.

Surveys that are not contemporary but with which the project instructions specify that a junction shall be made, are to be similarly treated. Where the instructions require a junction with surveys of the United States Corps of Engineers, such junctions are to be examined for adequacy (see **9348***D*), but the soundings should not be transferred.

*d. Adjustments of topographic and hydrographic data.*—Conflicts between contemporary topographic and hydrographic surveys should, of course, be adjusted by the field parties before the sur-

veys are forwarded to the Office (see **381** and **7827**). Those conflicts which are still found to exist should be adjusted in accordance with **7827**.

The reviewer may, *with discretion*, alter the symbol of a rock or change the amount it bares on a topographic sheet to bring it into agreement with a contemporary hydrographic sheet without an accompanying notation. But he should not change the character of a rock on a topographic survey, if the difference is consistent with the stage of tide at the time of the survey; an explanatory note should be added to the review of the topographic survey.

The smooth sheet should contain all information on the boat sheet when it is forwarded to the Office (see **7912**). Rocks and other hydrographic data inked on the boat sheet but not found on the smooth sheet and having no other authority should usually be referred to the field party for disposition, but where a satisfactory disposition cannot be made in this manner, they should, *with discretion*, be transferred to the smooth sheet.

*e. Datum note.*—The reviewer should check the correct application of the horizontal datum note in Stamp No. 42 on the smooth sheet.

Where the *dms.* and *dps.* of the reference station are found to agree with the values resulting from adjusted office computations, the word "adjusted" should be added, and if they are from field computations, the word "unadjusted" should be added. R.A.R. stations or buoys cited as reference stations should always be marked "unadjusted."

### *9343. Comparison With Prior Surveys*

This is one of the most important phases of the review. Its purpose is to make certain that the survey being reviewed is adequate to supersede the prior surveys, and to carry forward to the new survey in colored ink any important data not verified nor disproved by the new survey. After review it should be unnecessary for the chart compiler to consult prior surveys of an area covered by a modern survey, except as specifically mentioned in the written review.

Comprehensive evaluation of the material requires, among other considerations, that the reviewer utilize his knowledge of the accuracy and limitations of both modern and obsolete methods of surveying. Each prior survey must be individually compared with the present survey.

Important shoals and rocks on prior surveys should be considered separately with respect to the general character of the bottom, and where not reasonably verified in position or depth by the new survey, their correctness should be verified by reference to the original Sounding Records, with special regard to the type of sounding, reduction, plotting, and character of control. If found correct, the advisability of carrying them forward on the new survey should be considered. Errors found on a prior hydrographic or topographic survey, during the course of the review, should not be corrected, but the correct information should be indicated on the old sheet in red ink with a brief explanatory note. (See also **9344**.)

*a. Wire-drag surveys.*—Except where shoaler depths have been found by the new survey, all soundings and groundings on wire-drag surveys shall be carried forward in color on the new survey (see **7866**).

### *9344. Treatment of Rocks From Prior Surveys*

It will frequently be found that rocks shown on a prior survey have not been verified by the new survey or have been located in a slightly different position, or are of a somewhat different character. In the disposition of such cases all available information should be consulted and the following rules should be followed:

(*a*) *Rocks* shown on a prior hydrographic survey that are not authenticated in the Sounding Records or confirmed by other surveys should be considered as nonexistent and appropriately marked.

(*b*) Where the *position* of what is presumably the same rock differs on the new and the prior survey, the new position should be accepted as correct.

(*c*) Where an *adequate examination*, made by the new hydrographic or topographic survey in the vicinity of a rock or rocks, fails to disclose the existence as shown on the prior survey, the recommendation made by the hydrographer regarding its disposition, should be followed (see **842***L*).

*General statements* in a Descriptive Report, particularly of a *topographic survey*, that certain rocks on old surveys could not be found should be accepted only as proof that such rocks are not bare rocks. They should be transferred either as rocks awash or as sunken rocks, depending on the circumstances in each particular case.

(*d*) *Rocks* originating with a prior topographic survey and not disproved, that are to be carried forward should be shown in color on both the new topographic and the new hydrographic survey. *Rocks* that are to be carried forward from a prior hydrographic survey should be shown on the new hydrographic survey only.

(*e*) *Bare rocks* on a prior topographic or hydrographic survey, that are not shown or disproved on the new hydrographic or topographic survey should be carried forward as rocks awash.

(*f*) *Rocks awash* on a prior survey that are shown as sunken rocks on the new survey should be considered as rocks awash *unless* there is information on the new survey to show that the rock was not visible at low tide. In such cases the rock awash symbol should be shown in black ink on the new hydrographic survey and a note made in the Sounding Record.

(*g*) *Sunken rocks* on prior surveys, if not disproved by the new survey, should be carried forward as such.

(*h*) In general, the delineation *inside the low-water line* should be accepted as correct on the new survey, except that isolated rocks awash shown on a prior topographic survey, that are not located or disproved on the new survey, should be carried forward in color.

### *9345. Comparison With the Chart*

A comparison should be made with the largest-scale chart of the area, using one with the most recent print date (**1127**), for matters not already considered.

*a. Hydrography.*—Most of the charted data will already have been considered in the comparison with prior surveys. Attention need be given only to those data traceable to chart letters, field examinations, U. S. Coast Guard and U. S. Hydrographic Office Notices to Mariners, U. S. Corps of Engineers blueprints, or other sources. In general, comparison with surveys of other organizations should be restricted to charted information only. Only in exceptional cases is information from such sources actually carried forward on the new survey.

*b. Controlling depths.*—The controlling depth notes, which are charted in channels in which no soundings are charted, should be compared with the new survey. These notes appear in the form "24 feet June 1941". The notes are usually based on data furnished by the United States Corps of Engineers. It should be borne in mind that the notes are frequently based on data subsequent to the date of the survey and therefore supersede the survey information.

*c. Aids to navigation.*—The aids on the new survey should be compared with those on the latest *aid proof*, to see whether the positions and characteristics are substantially the same. They should be examined to see whether they satisfactorily mark the features or serve the purpose for which they are intended.

### *9346. Descriptive Report*

As the review progresses, each statement in the Descriptive Report and in the verifier's report should be considered and each paragraph should be checkmarked in red ink when disposed of. Where additional evidence has altered positive statements in the Descriptive Report, a marginal notation citing the disposition and authority should be lettered in red ink. Notations made in the Descriptive Report or the written

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review, after the review has been signed, must be initialed and dated. If these notations, or any alterations made on the smooth sheet, are of sufficient importance to affect charting and the survey has been applied to the chart, special notification must be made to the Nautical Chart Branch.

### *9347. Matters Left in Abeyance*

It is not always possible to dispose of all matters at the time a review is made, as for example, where an item must be referred to the field party for a recommendation. A book entitled "Matters to be Disposed of" is kept in the Surveys Branch, in which must be entered all matters left open on reviewed surveys which require some positive future action. All entries must be clear and explicit, and be in sufficient detail to make the meaning obvious without further study. Such entries should always be headed by the registry numbers of the affected surveys, diagram number, initials of the reviewer, and date. Each reviewer shall be responsible for following up and disposing of his own entries.

### *9348. Written Report*

The main purpose of the written review of a hydrographic survey is to state briefly and concisely, as a matter of permanent record, the pertinent facts relating to the survey. The review should serve as a guide to the chart compiler and as a basis for instructions for future additional field work. It should embody such important parts of the verifier's criticism as are found justified and should be made a matter of record, and should consider the broader phases of the survey, such as:

(*a*) The adequacy and sufficiency of the results of the field operations, for charting or other purposes.

(*b*) The results of comparative studies of old and new surveys to determine whether inconsistencies are the result of inaccuracies, or changes of artificial or natural origin.

(*c*) The investigation of charted shoals and other dangers to navigation in the light of the new survey for the purpose of determining which can be superseded and which should be retained.

(*d*) Suggestions for improvements in field and office methods, based on the reviewer's broad experience with many types of surveys.

Based on the review made, the written report should follow as closely as practicable the following outline:

*A. Shoreline and signals.*—The origin of the shoreline and off-lying topographic features and of the positions of the control stations shall be given. A cross-reference will be sufficient, where this information is included in the Descriptive Report (see **842***F* and *G*).

*B. Differences of depths at crossings.*—Include the result of **9342***a*.

*C. Depth curves.*—Include a statement as to the completeness with which the depth curves could be drawn, bearing in mind that it is sometimes impracticable in the interests of safety to run sounding lines sufficiently close to shore in rocky areas to permit delineation of all the inshore curves.

*D. Junctions.*—Include a statement as to the adequacy of the junctions (see **9342***c*). Important discrepancies that cannot be reconciled should be commented on, including probable causes.

*E. Comparison with prior surveys.*—State the results of **9343**. Prior surveys may be discussed singly or by groups depending on their character and, where possible, should be listed in chronological order.

After a brief digest of the comparative findings, conclude with a definite statement as to whether the prior survey is superseded or should be used to supplement the new survey. In some cases it may be advisable to recommend retention of bottom characteristics from the old survey.

List wire-drag surveys under a subhead and state whether the new survey depths are in harmony with the effective drag depths and whether any conflicts noted should be investigated. Wire-drag surveys are never to be superseded by ordinary hydrographic surveys.

*F. Comparison with chart.*—Give number and print date of chart (see **1127**) with which comparison was made, and the results of the comparison (see **9345**), under the following subheads:

*a. Hydrography.*—Include the results of **9345***a*. It may be advisable in some cases to recommend the retention of such information on the charts. This paragraph, when miscellaneous matters are considered, shall be concluded with a brief digest of the findings and a definite recommendation for retention or discontinuance of the items considered.

*b. Controlling depths.*—Include the results of **9345***b*. A brief statement that the present survey depths are in agreement or in conflict with the charted information will usually suffice.

*c. Aids to navigation.*—Give the results of **9345***c*. Where the new survey discloses that an aid in its official position is a menace rather than an aid to navigation, or a new unmarked danger is noted, a definite recommendation should be made.

*G. Condition of survey.*—Under the subheads (*a*) field work, (*b*) Sounding Records, (*c*) Descriptive Report, and (*d*) field plotting, state briefly whether the condition is satisfactory. Cases where the procedure is definitely wrong or fails to comply with the requirements of the Hydrographic Manual should be specifically mentioned. But it must be borne in mind that the Manual is infrequently supplemented or modified by Field and Office Memorandums, and that improvements in survey methods frequently result in procedures differing from those described in the Manual. The important parts of the verifier's criticism that are found justified and should be called to the attention of the hydrographer, should be included.

*H. Compliance with the project instructions.*—A brief statement that compliance with the instructions is satisfactory is usually the only comment required.

*I. Additional field work recommended.*—A brief statement that the survey is complete or satisfactory will apply to most surveys. Where further work is desirable, it will usually consist of examination of shoal indications, disposal of discrepancies, further development of outstanding oceanographic features, or elimination of *holidays*.

*J. Miscellaneous.*—Under this heading include only matters that cannot be covered under one of the other headings. If only one topic is included, the paragraph should have an appropriate heading.

*K. Superseded surveys.*—This paragraph is purely statistical. List all superseded surveys (wire-drag surveys excepted), accompanying each with a notation as to whether it is superseded "entirely" or "in part."

### *9349. Inspection of Hydrographic Survey*

After the hydrographic survey has been reviewed, it is critically inspected by the Assistant Chief of the Surveys Branch. The purpose of the inspection is to gain an over-all picture of the survey with regard to coverage, delineation of depth curves, and critical depths. The written review is examined to see that all pertinent facts have been adequately and clearly presented; particular attention being paid to the recommenda-

tions of the reviewer regarding the disposition of rocks and shoals from prior surveys and of charted information originating with other sources.

### 935. Approval by Administrative Officers

After the hydrographic survey has been verified, reviewed, and inspected, the completed sheet, the Descriptive Report, and the written review are examined thoroughly and read carefully and approved by four administrative officers in the Washington Office, who are charged with the prosecution of the field work and with the application of the results to the charts. Before its final approval the written review may be amended or supplemented.

After approval a copy of the written review is forwarded to the Chief of Party under whose direction the field work was accomplished, and he is requested to forward it to the hydrographer who was in immediate charge of the work, if the latter is no longer attached to his party. A copy of the written review of a survey on which office work was done at a Processing Office is also forwarded to the officer-in-charge of that office. This serves to call to the attention of those responsible any shortcomings in the field or office work and sets standards for future work of like character.

## 94. COMPUTATION OF BUOY POSITIONS

Positions of buoys should be computed as soon as possible after the field observations have been completed. Buoys are left at their stations only as long as they are needed for control of the hydrographic survey, so the computations should be made and the positions adjusted without delay in order to discover any deficiency in the observations which should be remedied before the buoys are removed. When many buoy stations are being located, as at the beginning of a field season or in extensive traverses, one or two persons should be assigned to this duty of computing and checking the computations. This assures the availability of the positions for use on the boat sheet in a short time without overtime work by personnel with other regular duties.

The observations should be recorded and the computations made on regular forms, preserved in three-ring binders made to take letter-size paper (8 by 10½ inches). Where there are many buoy stations it will be convenient to use three or four binders to segregate the records, as follows: (*a*) Buoy Data Book, (*b*) azimuths, (*c*) traverse computations, and (*d*) computations of tie-in buoys.

Of the four, the "Buoy Data Book" is the most important. It should be on the ship's bridge at all times during a buoy-control survey. In it should be kept all records of buoys anchored at, and removed from, stations, and all records of distance measurements. It should contain the complete record to date, and blank forms for future use, as follows:

Form 714, Abstract of Buoys Planted.
Form 777, Taut-wire Traverse Observations.
Form 713, Buoy to Buoy Distances by Bomb.
Form 715, Abstract of Bombed Distances.

The second binder should contain the azimuth data, including Form 718, Abstract of Buoy to Buoy Azimuths, and Form 720, Azimuth by Inclined Angles.

Where a buoy traverse is computed by using geographic positions, these computations are made on Form 27, Position Computation, Third-Order Triangulation, and these should be kept in a third binder.

Where there are buoy positions computed from observations to shore stations, it is advisable to use a fourth binder for these computations.

Where the total of the buoy positions is small, all of the above forms and computations can be conveniently kept in one binder.

Neither the observations nor the computations of a buoy traverse are self-checking, as are triangulation observations and computations. The accuracy of a buoy traverse is only known from its closure error, and frequently much surveying is done using buoy stations of a traverse before it is finally closed and this error is known. In order to ensure that errors are not made in the computations, every step must be checked, and duplicate position computations should be made for the geographic positions (see **9441**). Particular care should be given to the verification of traverse adjustments (see **944**).

### 941. Reduction of Sun-Azimuth Observations

The azimuths of a buoy traverse are usually derived from inclined angles measured between the sun and two buoys in range. The sun's altitude above the visible sea horizon must be measured simultaneously with each inclined angle. The inclined angle must be measured to the horizon in line with the buoys and not to some point on the superstructure of a buoy which is above or below the visible sea horizon.

The fundamental formula for the reduction of an inclined angle to the horizontal is:

$$\cos \Delta = \frac{\cos i}{\cos h}$$

in which $\Delta$ is the approximate horizontal angle, $i$ is the observed inclined angle, and $h$ is the observed altitude of the sun. This is the first formula given in **3338**.

For precise results such as are needed in buoy traverses a small correction known as the dip correction must be applied to each horizontal angle computed from the above formula. Buoy-traverse azimuths are computed on Form 720, Azimuth by Inclined Angle. The dip correction to be applied is explained on the back of this form and a graph is included to assist in the derivation of the correction.

Occasionally, it is necessary to determine the azimuth between a buoy and an elevated shore station beyond the visible sea horizon. An additional correction is required in such cases. Where the observed point on the shore station is above the visible sea horizon the correction, which is always positive, may be found from the following formula:

$$\text{correction } (\textit{in minutes}) = \frac{h' \tan h}{\sin \Delta \text{ (approximate)}}$$

in which $h'$ is the measured angular height, in minutes, of the observed point above the visible horizon, and $h$ and $\Delta$ are as in the preceding formula.

In the case of an elevated shore station, as described above, the corrected horizontal angle may also be obtained from the second formula given in **3338**.

### 942. Back Azimuth Correction

The sun azimuths in a buoy traverse are observed in the direction which is most convenient, depending on the relation between the directions of the line of buoys and the sun. The traverse, however, may not be computed in this same direction and when it is not, it is necessary to determine back azimuths just as in geodetic computations.

The difference between a forward and back azimuth is designated $\Delta\alpha$. Its value varies with latitude, azimuth, and the distance between buoys; its value is zero for north-south azimuths and a maximum for east-west azimuths. $\Delta\alpha$ in buoy traverses is identical with the same value in geodetic computations (see Form 27). Its approximate value may be found with sufficient accuracy for use in computing buoy traverses by using the dead-reckoning positions of the buoys, the taut-wire distances between them, and the sun azimuth. The computation may be made on Form 27, using five-place logarithms.

Where the back azimuth is needed, the observed azimuth should be corrected by $\Delta\alpha$, as found above, and the resulting azimuth used in the position computations of the buoys, after which, with these more accurate data, a new value of $\Delta\alpha$ is determined. If an appreciable difference is found, the geographic positions should be recomputed, using the azimuth corrected for the second value of $\Delta\alpha$.

## 943. Scope of Buoy Anchor Cable

Survey buoys anchored with only one cable, as is usual in the Coast and Geodetic Survey (see **283**), are free to swing around their anchors to various positions, depending on the direction and velocity of the current. The horizontal distance between the buoy and its anchor is called the *scope*.

The scope varies with the length and weight of the anchor cable, the type of buoy structure, the depth of water, and the method of anchoring (see **2836**), as well as with the velocity of current. Scope is difficult to determine accurately because of the many variable factors; and accurate experiments have not been made, on which to base empirical formulas. Where scope is appreciable, an allowance should be made for it in buoy computations and even where their positions are determined graphically.

Scope should be determined and allowed for in a standard manner. Where buoys are anchored with the cable recommended in **2832**, the following formulas have been found to give approximate scope with sufficient accuracy for various estimated current velocities, and for galvanized wire rope and chain.

In a weak current $S=1.8288(L-D)$.

In a moderate current $S=1.3716(L-D)+0.4072\sqrt{L^2-D^2}$.

In a strong current $S=0.9144(L-D+\sqrt{L^2-D^2})$.

in which $S$ is the scope (*in meters*), $D$ is the depth of water (*in fathoms*), and $L$ is the total length of anchor cable (*in fathoms*).

Where a relieving buoy is used, the horizontal distance (*in meters*) between the relieving buoy and the buoy structure must be added to the resulting $S$ values. The length $L$ must be reduced where the anchor cable is found to be fouled on the anchor, or where its effective length is reduced from any cause.

Provision may be made to measure the approximate scope, by anchoring a small marker buoy to the anchor of the survey buoy by a light line. The length of this line should only slightly exceed the depth of water plus the range of tide. The scope can then be derived from simultaneous depression angles measured to the two buoys when in range.

### *9431. Correction of Distance for Scope*

If the velocity and direction of the current at each buoy station are estimated at the time the distances are measured by taut wire, the measured distances may be corrected for scope to obtain distances between the buoy anchors. The scope can be computed as explained in **943**. For the computation, the azimuth between two buoy

anchors may be assumed to be the same as the azimuth between the respective buoys, and the lead of the anchor cable may be assumed to be the same as the direction of the current. Let the difference between the latter and the azimuth of the buoys be angle $A$. Then the scope multiplied by cosine $A$ is the correction for distance and the scope multiplied by sine $A$ is the eccentric distance normal to the line between buoys. The first value is used to correct measured distances to distances between buoy anchors; the second is used in correcting observed azimuths to azimuths between buoy anchors (see **9432**).

Care must be taken to apply the correction for distance with the proper sign. It is advisable to make a sketch of the line of buoys, showing the relative direction of the current at each buoy, for use as a guide in applying the corrections.

### *9432. Correction of Azimuth for Scope*

If the scale of the survey or the desired accuracy warrants it, the azimuths observed between buoy structures may be reduced to azimuths between their anchors by applying corrections for eccentricity. The scope is found as in **943** and reduced to a distance normal to the line between buoys as in **9431**. The eccentric correction is based on the relative positions of the two buoys and their respective anchors, bearing in mind that the measured distance and azimuth are between buoy structures. The eccentric correction for azimuth may be found from the following relation:

$$\tan \alpha = \frac{\text{eccentric distance normal to line of buoys}}{\text{distance between buoys}}$$

in which $\alpha$ is the small angular correction to azimuth, and the two distances are in the same units of length.

If the two eccentric distances normal to the line of buoys are combined, by addition if in opposite directions and by subtraction if in the same direction, only one computation is required to find the angle $\alpha$.

If logarithms are not used in the formula, the result will be the natural tangent of $\alpha$, which may be divided by 0.00029 (the natural tangent of 1 minute) to find the value of $\alpha$ in minutes. Using natural functions, the entire computation may be made with sufficient accuracy on a slide rule.

## 944. BUOY TRAVERSE

Buoy traverses are essentially the same as random traverses on land, except that the azimuths of the various portions of a buoy traverse are each measured independently, instead of being carried forward from an initial line through conventional horizontal angles measured at the turning points. The horizontal distances between buoy stations are measured by taut wire or log. With the azimuths and distances between adjacent buoy stations known, the positions in a traverse may be computed by one of the methods described in **9441** and **9442**.

Traverse computations are not difficult but attention must be paid to detail. The reduction of the distances and azimuths for scope, the computation of the positions, and the adjustment of a traverse, are operations in which errors are easily made unless the strictest attention is paid to the proper application of the various corrections. All abstracts should either be carefully checked or be prepared independently by two different persons as a check. Computations of buoy positions by the field party are assumed to be correct—they are not checked at the Washington Office.

### 9441. *Computation and Adjustment by Using Geographic Positions*

The positions in a buoy traverse may be computed by geographic positions either on Form 27, Position Computation, Third-Order Triangulation, or on Form 596, Position Computation Traverse. Form 27 is preferable because two positions can be computed on each copy of the form.

To check traverse computations, the positions should be computed independently by two different persons on separate copies of the form. If the results agree, one set of the computations may be destroyed.

TABLE 30.—*Adjustment of buoy traverse computed by geographic positions*

| Station name | Distance between stations | Sum distance | Azimuth | | Position from traverse computations | | | Adjustment for closure error | Adjusted position | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Meters* | *Meters* | ° | ′ | ° | ′ | *meters* | *Meters* | ° | ′ | *meters* | |
| Gal | -------- | -------- | ------ | ------ | ------ | ------ | ------ | ------ | 38 | 40 | 362.0 | Fixed position of initial buoy station. |
| | | | | | | | | | 74 | 49 | 970.9 | |
| Hem | 3,715.7 | 3,715.7 | 59 | 01.9 | 38 | 41 | 424.3 | −0.2 | 38 | 41 | 424.1 | |
| | | | | | 74 | 47 | 685.7 | +2.5 | 74 | 47 | 688.2 | |
| Fun | 2,432.5 | 6,148.2 | 57 | 03.9 | 38 | 41 | 1,747.1 | −0.4 | 38 | 41 | 1,746.7 | |
| | | | | | 74 | 46 | 94.2 | +4.2 | 74 | 46 | 98.4 | |
| Eat | 2,622.2 | 8,770.4 | 59 | 21.0 | 38 | 42 | 1,234.0 | −0.6 | 38 | 42 | 1,233.4 | |
| | | | | | 74 | 44 | 738.0 | +6.0 | 74 | 44 | 744.0 | |
| Dot | 3,897.9 | 12,668.3 | 60 | 37.5 | 38 | 43 | 1,296.6 | −0.8 | 38 | 43 | 1,295.8 | |
| | | | | | 74 | 42 | 240.7 | +8.6 | 74 | 42 | 249.3 | |
| Cop | 5,722.3 | 18,390.6 | 60 | 57.2 | 38 | 45 | 376.2 | −1.2 | 38 | 45 | 375.0 | |
| | | | | | 74 | 38 | 1,033.1 | +12.5 | 74 | 38 | 1,045.6 | |
| Tap | 4,375.9 | 22,766.5 | 58 | 31.8 | 38 | 46 | 811.0 | −1.5 | 38 | 46 | 809.5 | Fixed position of terminal buoy station. |
| | | | | | 74 | 36 | 200.2 | +15.5 | 74 | 36 | 215.7 | |

The adjustment of a traverse computed by geographic positions is shown in table 30. The fixed position of the initial buoy is entered in the "Adjusted position" column. The traverse computations are started from this position. In the column "Position from traverse computations," are listed the computed geographic positions of all the buoy stations in the traverse, including that of the terminal buoy, whose fixed position, in addition, is entered in the "Adjusted position" column. The differences in latitude and longitude between the computed and the fixed positions of the terminal buoy are entered on the last horizontal line in the column headed "Adjustment for closure error." This is the closure error of the traverse. This error is proportioned according to distance from the initial buoy and the proper proportional part is applied to each buoy in the traverse. The proportion is based on the progressive distances entered in the column headed "Sum distance."

Geographic positions of buoy stations should always be expressed in degrees, minutes, and *meters*. This eliminates the many conversions of seconds to meters, and vice versa, and the chance of making errors in such conversions.

### 9442. *Computation by Rectangular Coordinates*

The positions of stations in a line of traverse buoys may be computed by rectangular coordinates in a manner similar to the computation of land traverses which is explained in any good textbook on elementary surveying. This is the familiar computation by latitude and departure, modified to give correct geographic positions.

To make the computation, starting with a buoy whose position is fixed, known as the initial buoy, the buoy stations are tabulated in the order they are to be computed, with the azimuth and the distance between each pair of stations properly entered. Each distance multiplied by the cosine of the respective azimuth gives the plane latitude difference, and multiplied by the sine of the azimuth gives the plane longitude difference (departure). The progressive algebraic sums of latitude difference and longitude difference are next determined for each buoy station; differences of north latitude and west longitude are additive, and those of south latitude and east longitude are subtractive. The resulting sums are the values in meters, uncorrected for curvature, to be applied to the position of the initial station. They can be corrected by the simple methods described below with sufficient accuracy for the usual conditions.

The plane longitude differences must be corrected for convergence of the meridians. This correction must be computed for each pair of adjacent buoy stations and applied as a progessive algebraic sum to the progressive sums of longitude differences. The correction is zero on north-south lines, and so far as azimuth only is concerned, is a maximum on east-west lines. Special Publication No. 5 can be used in determining this correction. For the mean latitude of the line of buoys, take from the left-hand page the value (in hundredths of meters) of the change in length of 1 minute of longitude per minute of latitude. Multiply this value by the difference in longitude (in minutes) between the pairs of buoys, and then multiply this product by the difference in latitude (in minutes) between the forward buoy of the pair and the terminal buoy of the traverse. Or, the difference in length (in meters) of 1 minute of longitude at the latitudes of the forward buoy of the pair and the terminal buoy can be taken directly from the tables by subtraction, and multiplied by the difference in longitude (in minutes) between the pair of buoys. In the northern hemisphere the correction increases the longitude difference where the terminal buoy is south of the buoy to which the correction applies, and vice versa. The approximate latitudes and longitudes of the buoy stations as determined by dead reckoning are sufficiently accurate for use in determining the corrections.

There is also a latitude correction, which is applicable where the differences in longitude between successive buoys are large enough to warrant it. It varies with the latitude and is in proportion to the square of the difference in longitude. In latitude 40°, the correction is less than 3 meters for a longitude difference of 6,000 meters. For an ordinary traverse whose whole length is in the same general direction and with buoys approximately equally spaced, this correction will be satisfactorily taken care of in the adjustment of the closure error. Where it needs to be applied, the correction can be taken from Special Publication No. 5 under the appropriate latitude, and from the last column on the right-hand page, using the difference in longitude between successive pairs of buoys. The correction increases the latitude difference where the forward buoy of a pair is south of the preceding one, and vice versa. The correction is a progressive one, being applied to the plane latitude differences in the same manner as described above for the longitude corrections.

To find the closure error of a traverse computed by this method, convert the total corrected traverse values for the terminal buoy into minutes and meters and apply this to the geographic position of the initial buoy. Compare the results with the fixed position of the terminal buoy. The differences in latitude and longitude (in meters) are the closure error, which should be distributed through the traverse according to distance from the initial buoy.

In converting these traverse values into minutes of arc and meters, using Special Publication No. 5, use the metric value of 1 minute for the mid latitude of any traverse distance to convert latitudes—*but* the metric value of 1 minute of longitude for the latitude of the *terminal* buoy must be used to convert longitudes—not only for the terminal buoy itself but for each of the intermediate buoys.

In this method of computation the time saved by not having to compute and check the geographic positions, as in **9441**, will probably more than compensate for the additional time needed to apply the required corrections.

### *9443. Finding Location of Large Closure Error*

An accurate buoy traverse will generally close with an error of about 1 meter per statute mile of traverse, and where the closure error is much larger than this, a blunder may have been made in the computations. If there is a large error of closure, an analysis of a graphic plot showing the error will often give a clue to its location.

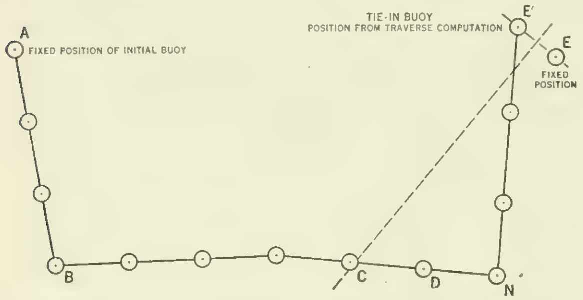



FIGURE 186.—To locate a large closure error in a buoy traverse.

Buoy positions are almost always plotted on the boat sheet as they are computed, for use in controlling the hydrography. This constitutes a graphic plot of the traverse in which the relation between the fixed position of the tie-in buoy and its position as computed from the traverse may be shown. Figure 186 illustrates a graphic plot of a traverse starting at buoy *A* and ending at Buoy *E*. The difference between the fixed position of buoy *E* and its computed position is the closure error *EE′*. If the azimuth of *EE′* is nearly the same as the azimuth of one of the lines of buoys, it is likely that the closure error is due to an error in one of the distances used in computing that part of the traverse.

Where the azimuth of *EE′* approximates none of the azimuths of the lines of buoys, the following test may disclose the location of a gross error in the field work or a blunder in the computations, causing an error in azimuth. A line is drawn joining *E* and *E′* and a perpendicular bisector is drawn at the midpoint, as shown in the figure. If it passes near a buoy position, an error in azimuth was probably made at that buoy. In the case illustrated, the azimuth between buoys *C* and *D* should first be checked, and reobserved if necessary, in attempting to find the error.

## 95. FORMS AND PUBLICATIONS

### 951. List of Forms

For convenient reference there are listed here the forms mentioned in the Hydrographic Manual; the list includes practically all the forms that are commonly needed in hydrographic surveying. Reference numbers given refer to those headings in the text under which the use of a form is described in more or less detail; no reference number is given opposite forms which are merely mentioned in the text. In requesting forms from the Office, all those listed whose numbers are not preceded by a letter should be ordered on Form 11*a*, but the experimental forms listed (those whose numbers are preceded by a letter) should be identified by both number and title.

| Form No. | Title | Reference number |
|---|---|---|
| 11 | Catalog of Forms and Stationery Used by the U. S. C. & G. S. | |
| 11a | Requisition for Forms and Stationery | 951 |
| 12 | Requisition for Instruments and General Property | 432 |
| 14 | Inventory of Instruments, General Property, etc | 433 |
| 20a | Monthly Report and Journal of Field Party | 156 |
| 21 | Statistics, Cost, and Summary of Field Work | 8515 |
| 25 | Computation of Triangles. | |
| 27 | Position Computation, Third-Order Triangulation. | |
| 28B | Geographic Positions | 7411 |
| 33 | Proposal (bond not required)—Supply Contract | 4231 |
| 38a | Magnetic Declination (Compass Declinometer). | |
| 51 | Signal Notice. | |
| 51a | Signal Notice (in Spanish). | |
| 62 | Sample Bottle Label. | |
| 248 | Tides: Comparison of Simultaneous Observations. | |
| 250 | Observations of Horizontal Angles | 2216 |
| 251 | Observations of Horizontal Directions | 2216 |
| 258 | Leveling Record—Tide Station | 1433 |
| 261 | Deviation Table. | |
| 270 | Record of Current Observations. | |
| 275 | Soundings | 81 |
| 277 | Tides. | |
| 354 | Observation of Compass Deviations. | |
| 355 | Computation of Compass Deviations. | |
| 356 | Analysis of ---------- Deviations. | |
| 376 | Soundings with Wire | 81 |
| 382 | Reduction to Center. | |
| 411 | Wire-drag Record | 81 |
| 413 | Letter Transmitting Field Records | 836 |
| 504 | Descriptive Report | 8411 |
| 508 | Proposal for Hire of Launch | 4231 |
| 509 | Lease of Launch | 4231 |
| 524 | Description of Recoverable Hydrographic or Topographic Station | 2351 |
| 525 | Description of Triangulation Station | 227 |
| 526 | Recovery Note, Triangulation Station | 2272 |
| 537 | Hydrographic Title Sheet | 8412 |
| 537a | Topographic Title Sheet. | |
| 567 | Landmarks for Charts | 8534 |
| 573 | Letter of Transmittal & Receipt for Transfer of Instruments or General Property | 433 |
| 596 | Position Computation, Traverse. | |
| 615 | Summary of Monthly Reports and Journals of Field Party and Cost Apportionment | 8515 |
| 623A | Photograph History | 1591 |
| 655 | Computation of Three-Point Problem | 2285 |
| 662 | Inverse Position Computation | 2511 |
| 665 | Triangle Computation Using Two Sides and Included Angle. | |
| 670 | Bomb Record | 8311 |
| 681 | Report—Tide Station | 1434 |
| 709 | Plane Coordinates. | |
| 712 | Tide Note for Hydrographic Sheet | 844c |
| 713 | Buoy to Buoy Distances by Bomb. | |
| 714 | Abstract of Buoys Planted | 2853 |
| 715 | Abstract of Bombed Distances | 2533 |
| 717 | Record of Temperatures, Salinities, and Theoretical Velocities | 6341 |
| 718 | Abstract of Buoy to Buoy Azimuths. | |
| 719 | Astronomic Sight for Hydrographic Control | 3382 |
| 720 | Azimuth by Inclined Angle | 941 |

| Form No. | Title | Reference number |
|---|---|---|
| 722 | R. A. R. and Dead Reckoning Abstract | 3377 |
| 757 | Requisition for Printing | 9137 |
| 777 | Taut-Wire Traverse Observations | 4466 |
| A-712 | Geographic Names. | |
| B-1528-5 | Graph of Temperatures and Salinites | 6342 |
| J-100-5 | Velocity Corrections | 5614 |
| M-238 | Memorandum—Immediate Attention | 844*b* |
| M-438 | Monthly Statistical Summary. | |
| M-961 | Progress of Office Work on Topographic Sheets | 8514 |
| M-962 | Progress of Office Work on Smooth Hydrographic Sheets | 8514 |
| M-963 | Progress of Office Work on Field Records | 8514 |
| M-996 | Verifier's Report of Hydrographic Survey | 9339 |
| M-1133-5 | Annual Statistical Report | 8516 |
| M-1683-1 | Check List and Office Statistics | 844*a* |
| R-233 | Abstract of Currents Observed. | |

## 952. Publications of the Coast and Geodetic Survey

The following field manuals and associated publications of the Coast and Geodetic Survey should be in the library of each vessel for reference, and officers should have personal copies of many of them. They are issued free for official use by the Bureau, but may be purchased only from the Superintendent of Documents, Govemment Printing Office, Washington, D. C., at the prices listed.

In the tabulation, the publications are grouped under the various classes of work, and are arranged according to their publication numbers. A complete list of the publications of the Coast and Geodetic Survey is contained in the List of Publications of the Department of Commerce, a copy of which may be obtained free on request.

| Special publication No. | | Price |
|---|---|---|
| | **ASTRONOMIC OBSERVATIONS** | |
| 14 | Determination of time, longitude, latitude, and azimuth | 65¢ |
| | **CARTOGRAPHY** | |
| 5 | Tables for a polyconic projection of maps and lengths of terrestrial arcs of meridian and parallels based upon Clarke's reference spheroid of 1866 | 30¢ |
| 57 | General theory of polyconic projections | 25¢ |
| 60 | A study of map projections in general | 5¢ |
| 68 | Elements of map projection with applications to map and chart construction | $1. 00 |
| 75 | Radio compass bearings | 5¢ |
| 205 | Cartography | 60¢ |
| | **GEOMAGNETISM** | |
| 96 | Instructions for the compensation of the magnetic compass | 15¢ |
| *Serial* 166 | Directions for magnetic measurements | 65¢ |
| | **HYDROGRAPHY** | |
| 118 | Construction and operation of the wire drag and sweep | 75¢ |
| | **LEVELING** | |
| 140 | Manual of first-order leveling | 15¢ |
| | **OCEANOGRAPHY** | |
| 108 | Velocity of sound in sea water | 5¢ |
| 147 | Measurement of salinity of sea water | 10¢ |

### TIDES AND CURRENTS

| Special publication No. | | Price |
|---|---|---|
| 135 | —Tidal datum planes | 30¢ |
| 196 | —Manual of tide observations | 15¢ |
| 215 | —Manual of current observations | 15¢ |
| 28 | —Tide and current glossary | 10¢ |

### TOPOGRAPHY

| | | |
|---|---|---|
| 144 | —Topographic manual | 30¢ |

### TRIANGULATION AND TRAVERSE

| | | |
|---|---|---|
| 8 | —Formulas and tables for the computation of geodetic positions | 30¢ |
| 28 | —Application of the theory of least squares to the adjustment of triangulation | 25¢ |
| 65 | —Instructions to lightkeepers on first-order triangulation | 5¢ |
| 71 | —Relation between plane rectangular coordinates and geographic positions | 10¢ |
| 120 | —Manual of first-order triangulation | 20¢ |
| 137 | —Manual of first-order traverse | 30¢ |
| 138 | —Manual of triangulation computation and adjustment | 60¢ |
| 145 | —Manual of second- and third-order triangulation and traverse | 25¢ |
| 158 | —Bilby steel tower for triangulation | 15¢ |
| 193 | —Manual of plane-coordinate computation | 35¢ |
| 194 | —Manual of traverse computation on the Lambert grid | 30¢ |
| 195 | —Manual of traverse computation on the transverse Mercator grid | 25¢ |
| 225 | —Manual of reconnaissance for triangulation | 15¢ |
| 234 | —Signal building | 15¢ |
| *Serial* 584 | —Azimuths from plane coordinates | 5¢ |
| *Serial* 624 | —Computation of traverse by plane coordinates | 5¢ |

## 953. Reference Books

Standard treatises on oceanography, surveying, navigation and seamanship, and other subjects associated with hydrographic surveying and the work of the Coast and Geodetic Survey should be available for reference in the library of each survey ship. The following lists of books are intended to be suggestive rather than inclusive:

### *9531. Publications on Hydrography and Oceanography*

| | |
|---|---|
| A study of the oceans | J. Johnstone |
| A textbook of oceanography | J. T. Jenkins |
| Admiralty manual of hydrographic surveying | British Admiralty |
| Dynamic meteorology and hydrography | V. Bjerknes |
| Field engineers bulletins | U. S. Coast and Geodetic Survey |
| Founders of oceanography and their work | W. A. Herdman |
| General instructions for hydrographic surveyors | British Admiralty |
| Hydrographic and geodetic surveying manual | H. O. publication No. 215 |
| Hydrographic review—published semiannually by | International Hydrographic Bureau |
| Hydrographical tables | M. Knudsen |
| Oceanography | H. B. Bigelow |
| Physical geography of the sea | M. F. Maury |
| Physics of the earth—Vol. V—oceanography | National Research Council |
| Science of the sea | G. H. Fowler and E. J. Allen |
| Tables of the velocity of sound in pure water and sea water | British Admiralty |
| The Oceans: their physics, chemistry, and general biology | H. U. Svedrup, M. W. Johnson, and R. H. Fleming |
| The sea | H. A. Marmer |
| The tide | H. A. Marmer |

### *9532. Publications on Navigation and Seamanship*

| | |
|---|---|
| A glossary of sea terms | G. Bradford |
| Altitude, azimuth, and line of position | H. O. publication No. 200 |
| American ephemeris and nautical almanac | U. S. Naval Observatory |
| American nautical almanac | U. S. Naval Observatory |
| American practical navigator—Bowditch | H. O. publication No. 9 |
| Azimuths of celestial bodies of declination 24° to 70° | H. O. publication No. 120 |
| Azimuths of the sun and other celestial bodies of declination 0° to 23° | H. O. publication No. 71 |
| Dead reckoning altitude and azimuth table—Ageton | H. O. publication No. 211 |
| International code signals, Vol. I., visual | H. O. publication No. 87 |
| Merchant vessels of the United States | Bureau of Customs |
| Modern marine engineer's manual | A. Osbourne |
| Modern seamanship | A. M. Knight |
| Modern shipfitter's handbook | W. E. Swanson |
| Naval institute proceedings—published monthly by | U. S. Naval Institute |
| Navigator's compendium | A. J. Tellier |
| Navigation and nautical astronomy | B. Dutton |
| Navigation tables for mariners and aviators—Dreisonstok | H. O. publication No. 208 |
| Piloting, seamanship and small boat handling | C. F. Chapman |
| Pocket book of ship materials and their uses | H. H. Thayer |
| Position tables for aerial and surface navigation | H. O. publication No. 209 |
| Practical air navigation | Civil Aeronautics Administration Bulletin No. 24 |
| Practical manual of the compass | U. S. Naval Institute |
| Principles of naval architecture (2 volumes) | H. E. Rossell and L. B. Chapman |
| Radio aids to navigation | H. O. publication No. 205 |
| Radio weather aids to navigation | H. O. publication No. 206 |
| Shipfitting practice | State of Pennsylvania Bulletin No. 345 |
| Simultaneous altitudes and azimuths of celestial bodies | H. O. publication No. 201 |
| Standard seamanship for the merchant service | F. Riesenberg |
| Tables of computed altitude and azimuth in 7 volumes | H. O. publication No. 214 |
| The naval artificer's manual | U. S. Navy, Bureau of Construction and Repair |
| The rules of the nautical road | R. F. Farwell |
| The Sumner line of position furnished ready to lay down on the chart by means of tables of simultaneous hour angle and azimuth of celestial bodies | H. O. publication Nos. 203 and 204 |
| Treatise on navigation and nautical astronomy, including the theory of compass deviations | W. C. P. Muir |
| Watch officer's guide | U. S. Naval Institute |

### *9533. Publications on Surveying and Astronomy*

| | |
|---|---|
| A textbook of geodetic astronomy | J. F. Hayford |
| A treatise on practical astronomy | C. L. Doolittle |
| Aerophotography and aerosurveying | J. W. Bagley |
| Analytical computations in aerial photogrammetry | Photogrammetric Engineering, Vol. VII, No. 4 |
| Elements of precise surveying and geodesy | M. Merriman |
| Field book of the skies | W. T. Olcott |

| | |
|---|---|
| Logarithms of sines and tangents for every second | R. Shortrede |
| Logarithmic tables (7 place) | R. Vega |
| Manual of astronomy | C. A. Young |
| Manual of spherical and practical astronomy | W. Chauvenet |
| Natural sines and cosines (8 place) | U. S. Coast and Geodetic Survey |
| Notes on the compilation of planimetric line maps | U. S. Coast and Geodetic Survey |
| Practical astronomy | G. L. Hosmer |
| Principles and practices of surveying, elementary surveying, Vol. I | C. B. Breed and G. L. Hosmer |
| Principles and practices of surveying, higher surveying, Vol. II | C. B. Breed and G. L. Hosmer |
| Surveying | War Department Technical Manual No. 5–235 |
| Surveying from air photographs | Captain M. Hotine, R. E. |
| Topographic drafting | War Department Technical Manual No. 5–230 |
| Topographical mapping from high oblique air photographs | Photogrammetric Engineering, Vol. VIII, No. 1 |

### *9534. Miscellaneous Publications*

| | |
|---|---|
| A textbook of sound | A. B. Wood |
| Acoustics | G. W. Stewart and R. B. Lindsay |
| Aeronautical meteorology | G. F. Taylor |
| American civil engineers' pocketbook | T. Merriman |
| Fundamentals of radio | F. E. Terman |
| Geophysical exploration | C. A. Heiland |
| Handbook of chemistry and physics | C. D. Hodgman (Chemical Rubber Publishing Co.) |
| Instructions to marine meteorological observers | U. S. Weather Bureau Circular M |
| Introduction to modern physics | F. K. Richtmyer |
| Mechanical engineers' handbook | L. S. Marks |
| Physics | E. Hausmann and E. P. Slack |
| Physics of the air | W. J. Humphreys |
| Pocket companion for engineers | Carnegie Steel Company |
| Radio engineering | F. E. Terman |
| Radio engineering handbook | K. Henney |
| Standard handbook for electrical engineers | F. F. Fowle |
| Suggestions to authors | U. S. Geological Survey |

## 954. RUBBER STAMPS FOR HYDROGRAPHIC SURVEYS

To facilitate the recording of hydrographic survey data, standard stamps have been designed for use in the records. In addition to those in table 31, a dating stamp may be used for dates in the Records, and special stamps will be furnished, if requested, for stamping the name of the vessel and the general locality in the Records.

The following is a tabular list of standard rubber stamps, that may be requisitioned from the Office by number, arranged according to various types of surveys. These stamps make obsolete former stamps numbered 1, 2, 3, 4, 5, 14, 15, 16, 17, 18, 19, 21, 22, 23, and 26.

Table 31.—*Rubber stamps for survey records*

| Stamp No. | Title of stamp, *or use* | Use described and facsimile in | For inshore handlead surveys | For inshore surveys by fathogram | For ship surveys (excluding R.A.R.) | For R.A.R. surveys |
|---|---|---|---|---|---|---|
| 20 | *Weather* | -------- | X | X | X | X |
| 24 | *For log readings, etc., in Sounding Record* | **8146** | -------- | -------- | X | X |
| 31 | Graphic record—*used on ends of fathograms* | **57** | -------- | X | X | X |
| 32 | Personnel—*duties of personnel* | **8131** | X | X | X | X |
| 33 | Sounding apparatus—*apparatus used and calibration* | **8132** | X | X | X | X |
| 34 | *Time and distance to and from work* | **8133** | X | X | X | X |
| 35 | *Comparison of sounding apparatus with standard* | **8134** | X | X | X | X |
| 36 | *Verification of sextants, etc.* | **816** | X | X | X | X |
| 37 | Statistics—*statistics of field work* | **8161** | X | X | X | X |
| 38 | Processing—*for reduction of Sounding Record* | **824** | X | X | X | X |
| 39 | Line begins—*used at beginning of sounding line* | **815** | X | X | X | X |
| 40 | *For initials of observer, etc., for various uses* | -------- | -------- | -------- | X | X |
| 41 | *For position number, etc., on end of chronograph tapes* | **6854** | -------- | -------- | -------- | X |
| 42 | Hydrographic survey—*for use on smooth sheet* | **746** | X | X | X | X |

## 96. TABLES

In this section is included a variety of tables, diagrams, and lists, which the hydrographer may need to use repeatedly without reference to the text. Most of them have been prepared especially for convenient use in hydrographic surveying, and others are not readily available elsewhere.

### 961. Velocity of Sound Tables

The velocity of sound in sea water is of supreme importance in hydrographic surveying, since most of the depths are now measured by echo sounding and much of the control of offshore hydrography is by Radio Acoustic Ranging (R.A.R.). It is necessary to use the velocity of sound in sea water in connection with both echo sounding (see **561**) and R.A.R. (see **636**). Two methods of deriving the velocity of sound from the observed physical characteristics of the water are provided: (*a*) from tables, and (*b*) from diagrams. Velocities derived from the tables will be slightly more accurate than those scaled from the diagrams, although the latter should be sufficiently accurate for all uses in hydrographic surveying.

#### *9611. Velocity of Sound Computations*

If the temperature and salinity of sea water at a specific depth are known, the velocity of sound at that depth may be derived from tables 32, 33, and 34. These tables are based on Tables of the Velocity of Sound in Pure Water and Sea Water, H. D. 282, published by the Hydrographic Department of the British Admiralty.

In table 32 are given the velocities (in meters per second) for various temperatures at surface atmospheric pressure and at an assumed salinity of 35.0 °/₀₀. The correction to be applied for any other salinity is given in table 33; it is subtractive for salinities less than 35.0 °/₀₀ and additive for salinities above 35.0 °/₀₀. The correction for pressure at latitude 45° is given in table 34; it is always additive. The pressure correction varies not only with hydrostatic pressure, but also with gravity and therefore slightly with latitude; but the mean values in table 34 are sufficiently accurate for all surveying purposes. The pressure correction is nearly proportional to depth, and for depths less than 1,000 fathoms, it may be found with sufficient accuracy by dividing the depth (in fathoms) by 30—the result being the correction in meters per second.

TABLE 32.—*Velocity of sound in sea water—in meters per second, at surface atmospheric pressure and salinity 35 °/₀₀.*

[Enter this table with the temperature. Apply a correction for salinity from table 33, and a correction for pressure from table 34.]

| Temp. °C. | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| −1 | 1440. 8 | 40. 3 | 39. 9 | 39. 4 | 38. 9 | 38. 5 | 38. 0 | 37. 5 | 37. 1 | 36. 6 |
| −0 | 1445. 4 | 45. 0 | 44. 5 | 44. 0 | 43. 6 | 43. 1 | 42. 7 | 42. 2 | 41. 7 | 41. 3 |
| 0 | 1445. 4 | 45. 9 | 46. 3 | 46. 8 | 47. 3 | 47. 7 | 48. 2 | 48. 6 | 49. 1 | 49. 5 |
| 1 | 1450. 0 | 50. 4 | 50. 9 | 51. 3 | 51. 8 | 52. 2 | 52. 7 | 53. 1 | 53. 5 | 54. 0 |
| 2 | 1454. 4 | 54. 9 | 55. 3 | 55. 7 | 56. 2 | 56. 6 | 57. 1 | 57. 5 | 57. 9 | 58. 4 |
| 3 | 1458. 8 | 59. 2 | 59. 6 | 60. 1 | 60. 5 | 60. 9 | 61. 4 | 61. 8 | 62. 2 | 62. 6 |
| 4 | 1463. 1 | 63. 5 | 63. 9 | 64. 3 | 64. 7 | 65. 2 | 65. 6 | 66. 0 | 66. 4 | 66. 8 |
| 5 | 1467. 2 | 67. 6 | 68. 0 | 68. 4 | 68. 8 | 69. 3 | 69. 7 | 70. 1 | 70. 5 | 70. 9 |
| 6 | 1471. 3 | 71. 7 | 72. 1 | 72. 5 | 72. 9 | 73. 3 | 73. 7 | 74. 1 | 74. 5 | 74. 9 |
| 7 | 1475. 3 | 75. 7 | 76. 1 | 76. 5 | 76. 9 | 77. 3 | 77. 6 | 78. 0 | 78. 4 | 78. 8 |
| 8 | 1479. 2 | 79. 6 | 80. 0 | 80. 3 | 80. 7 | 81. 1 | 81. 5 | 81. 9 | 82. 2 | 82. 6 |
| 9 | 1483. 0 | 83. 4 | 83. 7 | 84. 1 | 84. 5 | 84. 8 | 85. 2 | 85. 6 | 86. 0 | 86. 3 |
| 10 | 1486. 7 | 87. 1 | 87. 4 | 87. 8 | 88. 1 | 88. 5 | 88. 9 | 89. 2 | 89. 6 | 89. 9 |
| 11 | 1490. 3 | 90. 7 | 91. 0 | 91. 4 | 91. 7 | 92. 1 | 92. 4 | 92. 8 | 93. 1 | 93. 5 |
| 12 | 1493. 8 | 94. 2 | 94. 5 | 94. 8 | 95. 2 | 95. 5 | 95. 9 | 96. 2 | 96. 6 | 96. 9 |
| 13 | 1497. 2 | 97. 6 | 97. 9 | 98. 2 | 98. 6 | 98. 9 | 99. 2 | 99. 6 | 99. 9 | 1500. 2 |
| 14 | 1500. 6 | 00. 9 | 01. 2 | 01. 5 | 01. 9 | 02. 2 | 02. 5 | 02. 8 | 03. 2 | 03. 5 |
| 15 | 1503. 8 | 04. 1 | 04. 4 | 04. 7 | 05. 1 | 05. 4 | 05. 7 | 06. 0 | 06. 3 | 06. 6 |
| 16 | 1506. 9 | 07. 2 | 07. 6 | 07. 9 | 08. 2 | 08. 5 | 08. 8 | 09. 1 | 09. 4 | 09. 7 |
| 17 | 1510. 0 | 10. 3 | 10. 6 | 10. 9 | 11. 2 | 11. 5 | 11. 8 | 12. 1 | 12. 4 | 12. 7 |
| 18 | 1513. 0 | 13. 3 | 13. 6 | 13. 9 | 14. 1 | 14. 4 | 14. 7 | 15. 0 | 15. 3 | 15. 6 |
| 19 | 1515. 9 | 16. 2 | 16. 4 | 16. 7 | 17. 0 | 17. 3 | 17. 6 | 17. 9 | 18. 1 | 18. 4 |
| 20 | 1518. 7 | 19. 0 | 19. 2 | 19. 5 | 19. 8 | 20. 1 | 20. 3 | 20. 6 | 20. 9 | 21. 2 |
| 21 | 1521. 4 | 21. 7 | 22. 0 | 22. 2 | 22. 5 | 22. 8 | 23. 0 | 23. 3 | 23. 6 | 23. 8 |
| 22 | 1524. 1 | 24. 4 | 24. 6 | 24. 9 | 25. 2 | 25. 4 | 25. 7 | 25. 9 | 26. 2 | 26. 4 |
| 23 | 1526. 7 | 27. 0 | 27. 2 | 27. 5 | 27. 7 | 28. 0 | 28. 2 | 28. 5 | 28. 7 | 29. 0 |
| 24 | 1529. 2 | 29. 5 | 29. 7 | 30. 0 | 30. 2 | 30. 5 | 30. 7 | 31. 0 | 31. 2 | 31. 5 |
| 25 | 1531. 7 | 31. 9 | 32. 2 | 32. 4 | 32. 7 | 32. 9 | 33. 1 | 33. 4 | 33. 6 | 33. 9 |
| 26 | 1534. 1 | 34. 3 | 34. 6 | 34. 8 | 35. 0 | 35. 3 | 35. 5 | 35. 7 | 36. 0 | 36. 2 |
| 27 | 1536. 4 | 36. 7 | 36. 9 | 37. 1 | 37. 4 | 37. 6 | 37. 8 | 38. 0 | 38. 3 | 38. 5 |
| 28 | 1538. 7 | 38. 9 | 39. 2 | 39. 4 | 39. 6 | 39. 8 | 40. 0 | 40. 3 | 40. 5 | 40. 7 |
| 29 | 1540. 9 | 41. 1 | 41. 4 | 41. 6 | 41. 8 | 42. 0 | 42. 2 | 42. 4 | 42. 7 | 42. 9 |

TABLE 33.—*Salinity corrections.—Corrections in meters per second, to be applied to the velocities in table 32 to account for salinity*

[Enter this table with the salinity and temperature of water in °C. at the depth. When the salinity is more than 35 ‰ the correction is additive; when less, it is subtractive.]

| Salinity ‰ | Temperature °C. at depth | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| 0 | −46.1 | −44.4 | −42.4 | −40.6 | −39.2 | −38.5 | −38.8 |
| 5.0 | −39.5 | −38.1 | −36.4 | −34.8 | −33.6 | −32.9 | −33.0 |
| 10.0 | −32.8 | −31.7 | −30.3 | −29.0 | −27.9 | −27.2 | −27.2 |
| 15.0 | −26.2 | −25.4 | −24.2 | −23.2 | −22.2 | −21.6 | −21.5 |
| 20.0 | −19.6 | −19.0 | −18.2 | −17.4 | −16.6 | −16.0 | −15.7 |
| 21.0 | −18.3 | −17.7 | −17.0 | −16.3 | −15.5 | −15.0 | −14.7 |
| 22.0 | −17.0 | −16.4 | −15.8 | −15.2 | −14.4 | −13.9 | −13.6 |
| 23.0 | −15.7 | −15.2 | −14.5 | −14.0 | −13.3 | −12.8 | −12.6 |
| 24.0 | −14.3 | −13.9 | −13.3 | −12.8 | −12.2 | −11.8 | −11.5 |
| 25.0 | −13.0 | −12.6 | −12.1 | −11.6 | −11.1 | −10.7 | −10.5 |
| 26.0 | −11.7 | −11.4 | −10.9 | −10.5 | −10.0 | −9.6 | −9.4 |
| 27.0 | −10.4 | −10.1 | −9.7 | −9.3 | −8.9 | −8.5 | −8.4 |
| 28.0 | −9.1 | −8.8 | −8.5 | −8.1 | −7.8 | −7.4 | −7.4 |
| 29.0 | −7.8 | −7.6 | −7.3 | −7.0 | −6.7 | −6.4 | −6.3 |
| 30.0 | −6.5 | −6.4 | −6.1 | −5.8 | −5.5 | −5.4 | −5.2 |
| 30.2 | −6.2 | −6.1 | −5.8 | −5.6 | −5.3 | −5.1 | −5.0 |
| 30.4 | −6.0 | −5.8 | −5.6 | −5.3 | −5.1 | −4.9 | −4.8 |
| 30.6 | −5.7 | −5.6 | −5.3 | −5.1 | −4.8 | −4.7 | −4.6 |
| 30.8 | −5.5 | −5.3 | −5.1 | −4.9 | −4.6 | −4.5 | −4.4 |
| 31.0 | −5.2 | −5.0 | −4.8 | −4.6 | −4.4 | −4.3 | −4.2 |
| 31.2 | −4.9 | −4.8 | −4.6 | −4.4 | −4.2 | −4.1 | −4.0 |
| 31.4 | −4.7 | −4.6 | −4.3 | −4.2 | −4.0 | −3.9 | −3.8 |
| 31.6 | −4.4 | −4.3 | −4.1 | −4.0 | −3.7 | −3.6 | −3.5 |
| 31.8 | −4.2 | −4.0 | −3.8 | −3.7 | −3.5 | −3.4 | −3.3 |
| 32.0 | −3.9 | −3.8 | −3.6 | −3.5 | −3.3 | −3.2 | −3.1 |
| 32.2 | −3.6 | −3.5 | −3.4 | −3.3 | −3.1 | −3.0 | −2.9 |
| 32.4 | −3.4 | −3.3 | −3.1 | −3.0 | −2.9 | −2.8 | −2.7 |
| 32.6 | −3.1 | −3.0 | −2.9 | −2.8 | −2.6 | −2.6 | −2.5 |
| 32.8 | −2.9 | −2.8 | −2.6 | −2.5 | −2.4 | −2.4 | −2.3 |
| 33.0 | −2.6 | −2.5 | −2.4 | −2.3 | −2.2 | −2.2 | −2.1 |
| 33.2 | −2.3 | −2.2 | −2.2 | −2.1 | −2.0 | −2.0 | −1.9 |
| 33.4 | −2.1 | −2.0 | −1.9 | −1.8 | −1.8 | −1.8 | −1.7 |
| 33.6 | −1.8 | −1.7 | −1.7 | −1.6 | −1.5 | −1.5 | −1.4 |
| 33.8 | −1.6 | −1.5 | −1.4 | −1.4 | −1.3 | −1.3 | −1.2 |
| 34.0 | −1.3 | −1.2 | −1.2 | −1.2 | −1.1 | −1.1 | −1.0 |
| 34.2 | −1.0 | −1.0 | −1.0 | −1.0 | −0.9 | −0.9 | −0.8 |
| 34.4 | −0.8 | −0.7 | −0.7 | −0.7 | −0.7 | −0.7 | −0.6 |
| 34.6 | −0.5 | −0.5 | −0.5 | −0.4 | −0.4 | −0.4 | −0.4 |
| 34.8 | −0.3 | −0.2 | −0.2 | −0.2 | −0.2 | −0.2 | −0.2 |
| 35.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35.2 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 35.4 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 |
| 35.6 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 |
| 35.8 | 1.1 | 1.0 | 1.0 | 0.9 | 0.9 | 0.8 | 0.8 |
| 36.0 | 1.4 | 1.3 | 1.2 | 1.1 | 1.1 | 1.0 | 1.0 |
| 36.2 | 1.7 | 1.6 | 1.4 | 1.3 | 1.3 | 1.2 | 1.2 |
| 36.4 | 1.9 | 1.8 | 1.7 | 1.6 | 1.5 | 1.4 | 1.4 |
| 36.6 | 2.2 | 2.0 | 1.9 | 1.8 | 1.8 | 1.7 | 1.6 |
| 36.8 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 |
| 37.0 | 2.7 | 2.6 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 |

TABLE 33.—*Salinity corrections.*—Continued

| Salinity ‰ | Temperature °C. at depth | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| 37.2 | 3. 0 | 2. 8 | 2. 6 | 2. 5 | 2. 4 | 2. 3 | 2. 2 |
| 37.4 | 3. 2 | 3. 0 | 2. 9 | 2. 8 | 2. 6 | 2. 5 | 2. 4 |
| 37.6 | 3. 5 | 3. 3 | 3. 1 | 3. 0 | 2. 9 | 2. 8 | 2. 7 |
| 37.8 | 3. 7 | 3. 6 | 3. 4 | 3. 2 | 3. 1 | 3. 0 | 2. 9 |
| 38.0 | 4. 0 | 3. 8 | 3. 6 | 3. 4 | 3. 3 | 3. 2 | 3. 1 |
| 38.2 | 4. 3 | 4. 0 | 3. 9 | 3. 6 | 3. 5 | 3. 4 | 3. 3 |
| 38.4 | 4. 6 | 4. 3 | 4. 1 | 3. 9 | 3. 7 | 3. 6 | 3. 5 |
| 38.6 | 4. 9 | 4. 6 | 4. 4 | 4. 2 | 4. 0 | 3. 8 | 3. 7 |
| 38.8 | 5. 1 | 4. 8 | 4. 6 | 4. 4 | 4. 2 | 4. 0 | 3. 9 |
| 39.0 | 5. 4 | 5. 1 | 4. 9 | 4. 6 | 4. 4 | 4. 2 | 4. 1 |
| 40.0 | 6. 7 | 6. 3 | 6. 0 | 5. 7 | 5. 5 | 5. 2 | 5. 1 |
| 41.0 | 8. 1 | 7. 6 | 7. 0 | 6. 8 | 6. 5 | 6. 4 | 6. 1 |

TABLE 34.—*Pressure corrections.—Corrections in meters per second, to be applied to the velocities in table 32 to account for the pressure or depth*

[Enter this table with the depth in fathoms and the temperature of water in °C. at the depth. Add this correction to the velocities in table 32.]

| Depths in fathoms | Temperature °C. at depth | | | | |
|---|---|---|---|---|---|
| | −2 | 5 | 10 | 15 | 20 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 1. 6 | 1. 6 | 1. 6 | 1. 6 | 1. 6 |
| 100 | 3. 3 | 3. 3 | 3. 3 | 3. 3 | 3. 3 |
| 150 | 5. 0 | 5. 0 | 4. 9 | 4. 9 | 4. 9 |
| 200 | 6. 7 | 6. 7 | 6. 6 | 6. 6 | 6. 6 |
| 250 | 8. 3 | 8. 3 | 8. 2 | 8. 2 | 8. 2 |
| 300 | 10. 0 | 10. 0 | 9. 9 | 9. 9 | 9. 9 |
| 350 | 11. 6 | 11. 6 | 11. 5 | 11. 5 | 11. 5 |
| 400 | 13. 3 | 13. 3 | 13. 2 | 13. 2 | 13. 2 |
| 450 | 15. 0 | 15. 0 | 14. 9 | 14. 8 | 14. 8 |
| 500 | 16. 7 | 16. 7 | 16. 6 | 16. 5 | 16. 5 |
| 550 | 18. 3 | 18. 3 | 18. 2 | 18. 1 | 18. 1 |
| 600 | 20. 0 | 20. 0 | 19. 9 | 19. 8 | 19. 8 |
| 650 | 21. 6 | 21. 6 | 21. 5 | 21. 4 | 21. 5 |
| 700 | 23. 2 | 23. 2 | 23. 1 | 23. 0 | 23. 1 |
| 750 | 24. 9 | 24. 9 | 24. 8 | 24. 7 | 24. 7 |
| 800 | 26. 5 | 26. 5 | 26. 4 | 26. 3 | 26. 3 |
| 850 | 28. 2 | 28. 2 | 28. 1 | 28. 0 | 27. 9 |
| 900 | 29. 9 | 29. 8 | 29. 7 | 29. 6 | 29. 5 |
| 950 | 31. 6 | 31. 5 | 31. 4 | 31. 2 | 31. 2 |
| 1,000 | 33. 2 | 33. 1 | 33. 0 | 32. 8 | 32. 8 |

TABLE 34.—*Pressure corrections.*—Continued

| Depths in fathoms | Temperature °C. at depth | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| 1,000 | | | | | | 33. 1 |
| 1,050 | 34. 9 | 34. 9 | 34. 9 | 34. 9 | 34. 9 | 34. 8 |
| 1,100 | 36. 5 | 36. 5 | 36. 5 | 36. 5 | 36. 5 | 36. 4 |
| 1,150 | 38. 2 | 38. 2 | 38. 2 | 38. 2 | 38. 2 | 38. 2 |
| 1,200 | 39. 8 | 39. 8 | 39. 8 | 39. 8 | 39. 8 | 39. 8 |
| 1,250 | 41. 5 | 41. 5 | 41. 5 | 41. 5 | 41. 5 | 41. 5 |
| 1,300 | 43. 2 | 43. 2 | 43. 1 | 43. 1 | 43. 1 | 43. 1 |
| 1,350 | 44. 8 | 44. 8 | 44. 8 | 44. 7 | 44. 7 | 44. 7 |
| 1,400 | 46. 5 | 46. 5 | 46. 5 | 46. 4 | 46. 4 | 46. 3 |
| 1,450 | 48. 1 | 48. 1 | 48. 1 | 48. 0 | 48. 0 | 47. 9 |
| 1,500 | 49. 8 | 49. 8 | 49. 8 | 49. 7 | 49. 7 | 49. 6 |
| 1,550 | 51. 4 | 51. 4 | 51. 4 | 51. 3 | 51. 3 | 51. 2 |
| 1,600 | 53. 1 | 53. 1 | 53. 1 | 53. 0 | 53. 0 | 52. 9 |
| 1,650 | 54. 7 | 54. 7 | 54. 7 | 54. 6 | 54. 6 | 54. 5 |
| 1,700 | 56. 4 | 56. 4 | 56. 4 | 56. 3 | 56. 3 | 56. 2 |
| 1,750 | 58. 0 | 58. 0 | 58. 0 | 57. 9 | 57. 9 | 57. 8 |
| 1,800 | 59. 7 | 59. 7 | 59. 6 | 59. 6 | 59. 5 | 59. 4 |
| 1,850 | 61. 3 | 61. 3 | 61. 2 | 61. 2 | 61. 1 | 61. 0 |
| 1,900 | 62. 9 | 62. 9 | 62. 8 | 62. 8 | 62. 7 | 62. 6 |
| 1,950 | 64. 6 | 64. 6 | 64. 5 | 64. 4 | 64. 4 | 64. 3 |
| 2,000 | 66. 2 | 66. 2 | 66. 1 | 66. 0 | 66. 0 | 65. 9 |
| 2,100 | 69. 5 | 69. 4 | 69. 4 | 69. 3 | 69. 2 | |
| 2,200 | 72. 8 | 72. 7 | 72. 7 | 72. 6 | 72. 5 | |
| 2,300 | 76. 1 | 76. 0 | 75. 9 | 75. 8 | 75. 7 | |
| 2,400 | 79. 3 | 79. 2 | 79. 2 | 79. 1 | 79. 0 | |
| 2,500 | 82. 5 | 82. 4 | 82. 4 | 82. 3 | 82. 1 | |
| 2,600 | 85. 8 | 85. 7 | 85. 7 | 85. 6 | 85. 4 | |
| 2,700 | 89. 1 | 89. 0 | 88. 9 | 88. 8 | 88. 7 | |
| 2,800 | 92. 3 | 92. 2 | 92. 1 | 92. 0 | 91. 9 | |
| 2,900 | 95. 6 | 95. 5 | 95. 4 | 95. 3 | 95. 1 | |
| 3,000 | 98. 9 | 98. 7 | 98. 6 | 98. 5 | 98. 3 | |
| 3,100 | 102. 1 | 101. 9 | 101. 8 | 101. 6 | 101. 4 | |
| 3,200 | 105. 3 | 105. 2 | 105. 0 | 104. 8 | 104. 6 | |
| 3,300 | 108. 5 | 108. 4 | 108. 2 | 108. 0 | 107. 8 | |
| 3,400 | 111. 7 | 111. 6 | 111. 3 | 111. 1 | 110. 9 | |
| 3,500 | 114. 9 | 114. 7 | 114. 5 | 114. 3 | 114. 0 | |
| 3,600 | 118. 1 | 117. 9 | 117. 7 | 117. 4 | 117. 2 | |
| 3,700 | 121. 3 | 121. 1 | 120. 8 | 120. 6 | 120. 3 | |
| 3,800 | 124. 5 | 124. 3 | 124. 0 | 123. 8 | 123. 5 | |
| 3,900 | 127. 7 | 127. 5 | 127. 2 | 127. 0 | 126. 7 | |
| 4,000 | 130. 9 | 130. 6 | 130. 3 | 130. 1 | 129. 8 | |

### *9612. Velocity From Diagrams*

The diagrams (figs. 187 and 188) may be used instead of the tables in **9611** to find velocities. These diagrams are based on the values in the tables but, owing to their small scale, the velocities cannot be derived with quite the accuracy that the tables will give. But if the values are interpolated carefully from the diagrams the resulting velocities should be sufficiently accurate for use in computing echo-sounding corrections.

One diagram is for velocities for the range of temperatures from 0° to 15° C. and

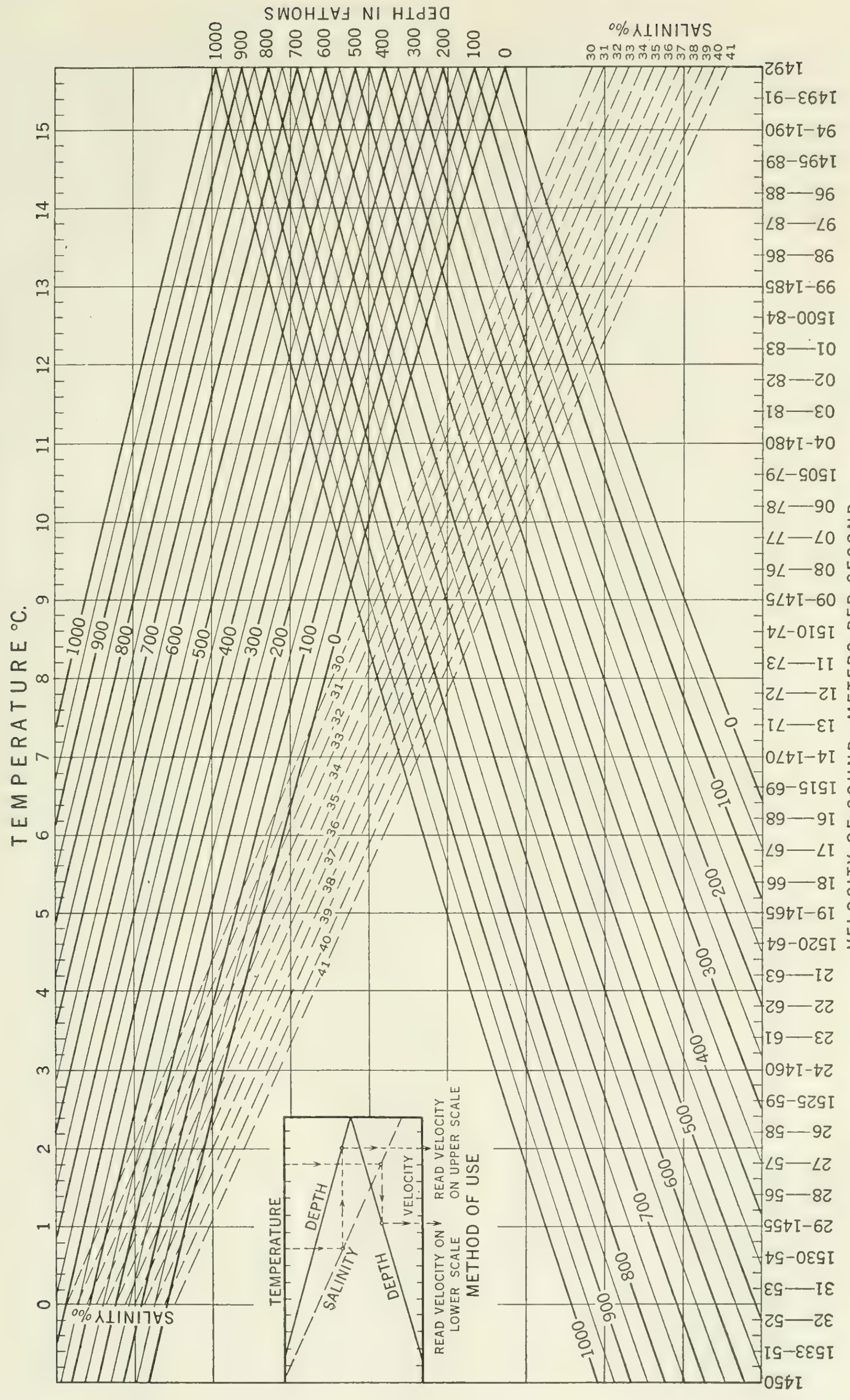



FIGURE 187.—Nomograph for derivation of velocity of sound in sea water (for temperatures from 0° to 15° centigrade).

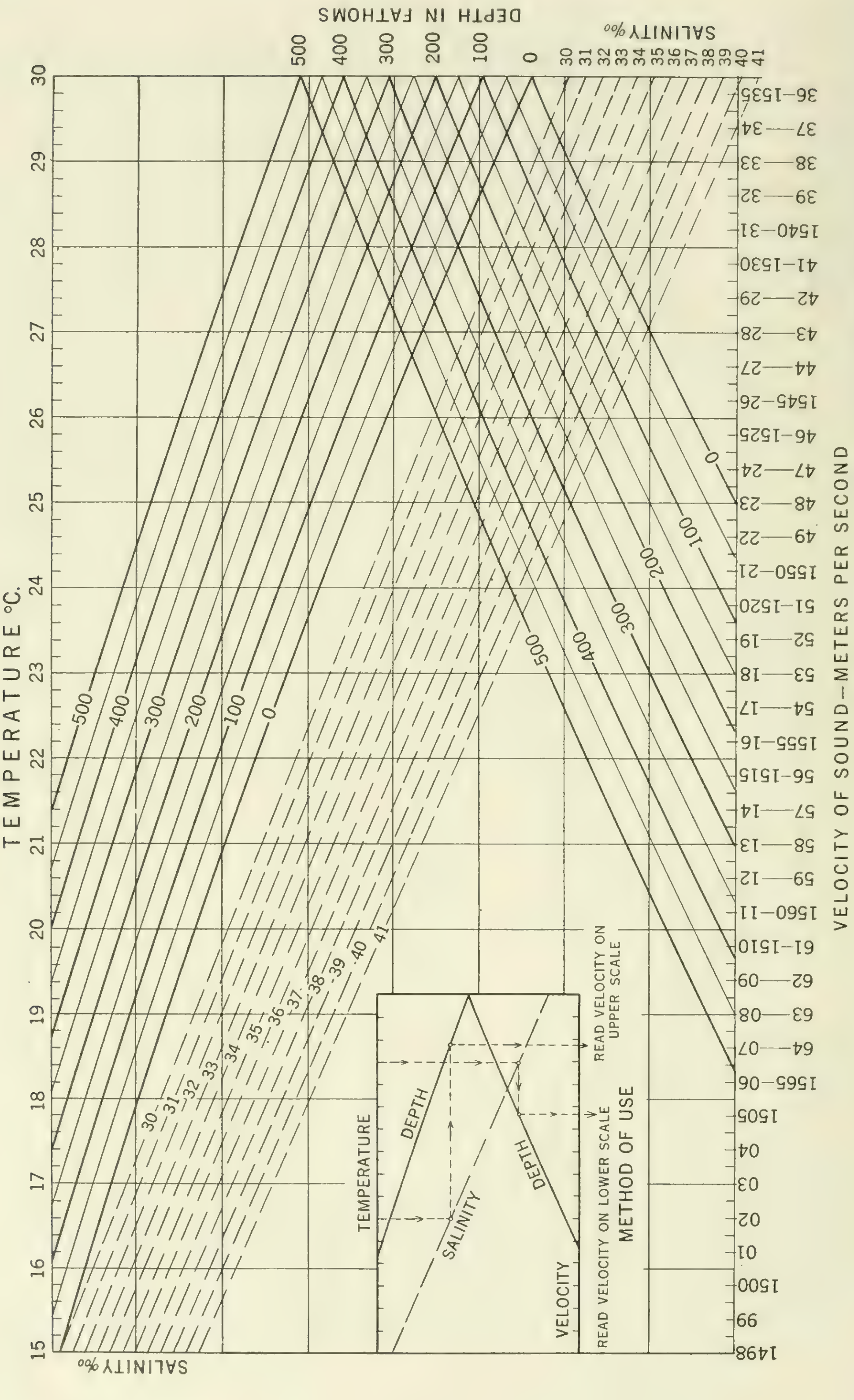



FIGURE 188.—Nomograph for derivation of velocity of sound in sea water (for temperatures from 15° to 30° centigrade).

the other is for the range of temperatures from 15° to 30° C. Both diagrams are used in the same way. Enter the diagram with the temperature at depth on the scale at the top of the diagram and drop vertically to the diagonal line representing the salinity, then follow horizontally to the diagonal line representing the depth of the observation, and from here drop vertically to the abscissa scale at the bottom of the diagram and read the velocity of sound. If the upper series of depth curves is used the upper of the two velocity scales should be used, but if the lower series of depth curves is used the velocity should be read from the lower of the two velocity scales.

### *9613. Velocity Correction Factors*

For deriving the factors used in computing velocity corrections to be applied to echo soundings, to account for the deviation of the actual velocity from the calibration velocity of the echo-sounding instrument, table 35 is given. The use of the factors is explained in **5613** and they are used in the example of velocity correction computations in table 20.

TABLE 35.—*Velocity correction factors*

| Actual velocity (*in meters per second*) | Calibration velocity (*in fathoms per second*) | | |
|---|---|---|---|
| | 800 | 810 | 820 |
| 1, 460 | −0. 00205 | −0. 01438 | −0. 02641 |
| 61 | −0. 00137 | −0. 01370 | −0. 02574 |
| 62 | −0. 00068 | −0. 01303 | −0. 02507 |
| 63 | 0. 00000 | −0. 01235 | −0. 02441 |
| 64 | +0. 00068 | −0. 01168 | −0. 02374 |
| 65 | +0. 00137 | −0. 01100 | −0. 02307 |
| 66 | +0. 00205 | −0. 01033 | −0. 02241 |
| 67 | +0. 00273 | −0. 00965 | −0. 02174 |
| 68 | +0. 00342 | −0. 00898 | −0. 02107 |
| 69 | +0. 00410 | −0. 00830 | −0. 02041 |
| 1, 470 | +0. 00478 | −0. 00763 | −0. 01974 |
| 71 | +0. 00547 | −0. 00695 | −0. 01907 |
| 72 | +0. 00615 | −0. 00628 | −0. 01840 |
| 73 | +0. 00684 | −0. 00560 | −0. 01774 |
| 74 | +0. 00752 | −0. 00493 | −0. 01707 |
| 75 | +0. 00820 | −0. 00425 | −0. 01640 |
| 76 | +0. 00889 | −0. 00358 | −0. 01574 |
| 77 | +0. 00957 | −0. 00290 | −0. 01507 |
| 78 | +0. 01025 | −0. 00223 | −0. 01440 |
| 79 | +0. 01094 | −0. 00155 | −0. 01374 |
| 1, 480 | +0. 01162 | −0. 00088 | −0. 01307 |
| 81 | +0. 01230 | −0. 00020 | −0. 01240 |
| 82 | +0. 01299 | +0. 00047 | −0. 01174 |
| 83 | +0. 01367 | +0. 00115 | −0. 01107 |
| 84 | +0. 01435 | +0. 00182 | −0. 01040 |
| 85 | +0. 01504 | +0. 00250 | −0. 00974 |
| 86 | +0. 01572 | +0. 00317 | −0. 00907 |
| 87 | +0. 01640 | +0. 00385 | −0. 00840 |
| 88 | +0. 01709 | +0. 00452 | −0. 00774 |
| 89 | +0. 01777 | +0. 00520 | −0. 00707 |
| 1, 490 | +0. 01846 | +0. 00587 | −0. 00640 |

TABLE 35.—*Velocity correction factors*—Continued

| Actual velocity (*in meters per second*) | Calibration velocity (*in fathoms per second*) | | |
|---|---|---|---|
| | 800 | 810 | 820 |
| 1,491 | +0.01914 | +0.00655 | −0.00573 |
| 92 | +0.01982 | +0.00722 | −0.00507 |
| 93 | +0.02051 | +0.00790 | −0.00440 |
| 94 | +0.02119 | +0.00857 | −0.00373 |
| 95 | +0.02187 | +0.00925 | −0.00307 |
| 96 | +0.02256 | +0.00992 | −0.00240 |
| 97 | +0.02324 | +0.01060 | −0.00173 |
| 98 | +0.02392 | +0.01127 | −0.00107 |
| 99 | +0.02461 | +0.01195 | −0.00040 |
| 1,500 | +0.02529 | +0.01262 | +0.00027 |
| 01 | +0.02597 | +0.01330 | +0.00093 |
| 02 | +0.02666 | +0.01397 | +0.00160 |
| 03 | +0.02734 | +0.01465 | +0.00227 |
| 04 | +0.02802 | +0.01532 | +0.00293 |
| 05 | +0.02871 | +0.01600 | +0.00360 |
| 06 | +0.02939 | +0.01667 | +0.00427 |
| 07 | +0.03008 | +0.01735 | +0.00493 |
| 08 | +0.03076 | +0.01802 | +0.00560 |
| 09 | +0.03144 | +0.01870 | +0.00627 |
| 1,510 | +0.03213 | +0.01937 | +0.00694 |
| 11 | +0.03281 | +0.02005 | +0.00760 |
| 12 | +0.03349 | +0.02073 | +0.00827 |
| 13 | +0.03418 | +0.02140 | +0.00894 |
| 14 | +0.03486 | +0.02208 | +0.00960 |
| 15 | +0.03554 | +0.02275 | +0.01027 |
| 16 | +0.03623 | +0.02342 | +0.01094 |
| 17 | +0.03691 | +0.02410 | +0.01160 |
| 18 | +0.03759 | +0.02478 | +0.01227 |
| 19 | +0.03828 | +0.02545 | +0.01294 |
| 1,520 | +0.03896 | +0.02613 | +0.01360 |
| 21 | +0.03964 | +0.02680 | +0.01427 |
| 22 | +0.04033 | +0.02748 | +0.01494 |
| 23 | +0.04101 | +0.02815 | +0.01560 |
| 24 | +0.04170 | +0.02883 | +0.01627 |
| 25 | +0.04238 | +0.02950 | +0.01694 |
| 26 | +0.04306 | +0.03018 | +0.01760 |
| 27 | +0.04375 | +0.03085 | +0.01827 |
| 28 | +0.04443 | +0.03153 | +0.01894 |
| 29 | +0.04511 | +0.03220 | +0.01961 |
| 1,530 | +0.04580 | +0.03288 | +0.02027 |
| 31 | +0.04648 | +0.03355 | +0.02094 |
| 32 | +0.04716 | +0.03423 | +0.02161 |
| 33 | +0.04785 | +0.03490 | +0.02227 |
| 34 | +0.04853 | +0.03558 | +0.02294 |
| 35 | +0.04921 | +0.03625 | +0.02361 |
| 36 | +0.04990 | +0.03693 | +0.02427 |
| 37 | +0.05058 | +0.03760 | +0.02494 |
| 38 | +0.05126 | +0.03828 | +0.02561 |
| 39 | +0.05195 | +0.03895 | +0.02627 |
| 1,540 | +0.05263 | +0.03963 | +0.02694 |

### *9614. Velocity Reduction Factors for R.A.R.*

Hydrographic surveys controlled by Radio Acoustic Ranging (R.A.R.) are plotted on smooth sheets by using an assumed velocity of sound of 1,460 meters per second. This velocity was chosen so that the corrections to the elapsed times to account for the actual velocity will always be positive. (See **7341** and **7631**.) Table 36 gives the factors by which the actual elapsed times may be multiplied to find the times to be used in plotting on smooth sheets on which the distance circles have been drawn for an assumed velocity of sound of 1,460 meters per second.

TABLE 36.—*Velocity reduction factors for R.A.R.*

[Factors for reducing elapsed time at actual velocity to corrected time at velocity of 1,460 meters per second.]

| Velocity | Factor | Velocity | Factor | Velocity | Factor |
|---|---|---|---|---|---|
| 1,461 | 1.00068 | 1,488 | 1.01918 | 1,515 | 1.03767 |
| 62 | 1.00137 | 89 | 1.01986 | 16 | 1.03836 |
| 63 | 1.00205 | 1,490 | 1.02055 | 17 | 1.03904 |
| 64 | 1.00274 | 91 | 1.02123 | 18 | 1.03973 |
| 65 | 1.00342 | 92 | 1.02192 | 19 | 1.04041 |
| 66 | 1.00411 | 93 | 1.02260 | 1,520 | 1.04110 |
| 67 | 1.00479 | 94 | 1.02329 | 21 | 1.04178 |
| 68 | 1.00548 | 95 | 1.02397 | 22 | 1.04246 |
| 69 | 1.00616 | 96 | 1.02466 | 23 | 1.04315 |
| 1,470 | 1.00685 | 97 | 1.02534 | 24 | 1.04384 |
| 71 | 1.00753 | 98 | 1.02603 | 25 | 1.04452 |
| 72 | 1.00822 | 99 | 1.02671 | 26 | 1.04520 |
| 73 | 1.00890 | 1,500 | 1.02740 | 27 | 1.04589 |
| 74 | 1.00958 | 01 | 1.02808 | 28 | 1.04658 |
| 75 | 1.01027 | 02 | 1.02877 | 29 | 1.04726 |
| 76 | 1.01096 | 03 | 1.02945 | 1,530 | 1.04794 |
| 77 | 1.01164 | 04 | 1.03013 | 31 | 1.04863 |
| 78 | 1.01233 | 05 | 1.03082 | 32 | 1.04932 |
| 79 | 1.01301 | 06 | 1.03151 | 33 | 1.05000 |
| 1,480 | 1.01370 | 07 | 1.03219 | 34 | 1.05068 |
| 81 | 1.01438 | 08 | 1.03288 | 35 | 1.05137 |
| 82 | 1.01507 | 09 | 1.03356 | 36 | 1.05205 |
| 83 | 1.01575 | 1,510 | 1.03425 | 37 | 1.05274 |
| 84 | 1.01644 | 11 | 1.03493 | 38 | 1.05342 |
| 85 | 1.01712 | 12 | 1.03562 | 39 | 1.05411 |
| 86 | 1.01781 | 13 | 1.03630 | 1,540 | 1.05479 |
| 87 | 1.01849 | 14 | 1.03699 | | |

465382—44——57

## 962. Standard Widths of Line

Standard widths of lines are printed by reference to which the draftsman can gage the width which is prescribed for use in any given class of drafting.

0.10 MILLIMETER = 0.0039 INCH

0.15 MILLIMETER = 0.0059 INCH

0.20 MILLIMETER = 0.0079 INCH

0.25 MILLIMETER = 0.0098 INCH

0.30 MILLIMETER = 0.0118 INCH

0.40 MILLIMETER = 0.0157 INCH

0.50 MILLIMETER = 0.0197 INCH

0.75 MILLIMETER = 0.0295 INCH

1.00 MILLIMETER = 0.0394 INCH

1.50 MILLIMETERS = 0.0591 INCH

2.00 MILLIMETERS = 0.0787 INCH

## 963. Miscellaneous Conversion Tables

For miscellaneous use several conversion tables are included which have various applications in hydrographic surveying.

Table 37.—*Linear distance conversion—fathoms-meters-feet-yards*

| | Fathoms to— | | Meters to— | | | Feet to— | | Yards to— |
|---|---|---|---|---|---|---|---|---|
| | Feet | Meters | Fathoms | Yards | Feet | Meters | Fathoms | Meters |
| 1 | 6 | 1. 82880 | 0. 54681 | 1. 09361 | 3. 28083 | 0. 30480 | 0. 16667 | 0. 91440 |
| 2 | 12 | 3. 65761 | 1. 09361 | 2. 18722 | 6. 56167 | 0. 60960 | 0. 33333 | 1. 82880 |
| 3 | 18 | 5. 48641 | 1. 64042 | 3. 28083 | 9. 84250 | 0. 91440 | 0. 50000 | 2. 74320 |
| 4 | 24 | 7. 31521 | 2. 18722 | 4. 37444 | 13. 12333 | 1. 21920 | 0. 66667 | 3. 65761 |
| 5 | 30 | 9. 14402 | 2. 73403 | 5. 46806 | 16. 40417 | 1. 52400 | 0. 83333 | 4. 57201 |
| 6 | 36 | 10. 97282 | 3. 28083 | 6. 56167 | 19. 68500 | 1. 82880 | 1. 00000 | 5. 48641 |
| 7 | 42 | 12. 80163 | 3. 82764 | 7. 65528 | 22. 96583 | 2. 13360 | 1. 16667 | 6. 40081 |
| 8 | 48 | 14. 63043 | 4. 37444 | 8. 74889 | 26. 24667 | 2. 43840 | 1. 33333 | 7. 31521 |
| 9 | 54 | 16. 45923 | 4. 92125 | 9. 84250 | 29. 52750 | 2. 74320 | 1. 50000 | 8. 22962 |

Table 38.—*Linear distance conversion—nautical miles-statute miles-kilometers*

| | Nautical Miles to— | | Statute Miles to— | | Kilometers to— | |
|---|---|---|---|---|---|---|
| | Statute miles | Kilometers | Nautical miles | Kilometers | Statute miles | Nautical miles |
| 1 | 1. 15155 | 1. 85325 | 0. 86839 | 1. 60935 | 0. 62137 | 0. 53959 |
| 2 | 2. 30311 | 3. 70650 | 1. 73678 | 3. 21869 | 1. 24274 | 1. 07918 |
| 3 | 3. 45466 | 5. 55975 | 2. 60518 | 4. 82804 | 1. 86411 | 1. 61878 |
| 4 | 4. 60621 | 7. 41300 | 3. 47357 | 6. 43739 | 2. 48548 | 2. 15837 |
| 5 | 5. 75776 | 9. 26625 | 4. 34196 | 8. 04674 | 3. 10685 | 2. 69796 |
| 6 | 6. 90932 | 11. 11950 | 5. 21036 | 9. 65608 | 3. 72822 | 3. 23756 |
| 7 | 8. 06087 | 12. 97275 | 6. 07875 | 11. 26543 | 4. 34959 | 3. 77715 |
| 8 | 9. 21242 | 14. 82600 | 6. 94714 | 12. 87478 | 4. 97096 | 4. 31674 |
| 9 | 10. 36398 | 16. 67925 | 7. 81553 | 14. 48413 | 5. 59233 | 4. 85633 |

Table 39.—*Temperature conversion*

CENTIGRADE TO FAHRENHEIT

| °C. | °F. | °C. | °F. | °C. | °F. | °C. | °F. | °C. | °F. |
|---|---|---|---|---|---|---|---|---|---|
| −2 | 28. 4 | 5 | 41. 0 | 12 | 53. 6 | 19 | 66. 2 | 26 | 78. 8 |
| −1 | 30. 2 | 6 | 42. 8 | 13 | 55. 4 | 20 | 68. 0 | 27 | 80. 6 |
| 0 | 32. 0 | 7 | 44. 6 | 14 | 57. 2 | 21 | 69. 8 | 28 | 82. 4 |
| 1 | 33. 8 | 8 | 46. 4 | 15 | 59. 0 | 22 | 71. 6 | 29 | 84. 2 |
| 2 | 35. 6 | 9 | 48. 2 | 16 | 60. 8 | 23 | 73. 4 | 30 | 86. 0 |
| 3 | 37. 4 | 10 | 50. 0 | 17 | 62. 6 | 24 | 75. 2 | 31 | 87. 8 |
| 4 | 39. 2 | 11 | 51. 8 | 18 | 64. 4 | 25 | 77. 0 | 32 | 89. 6 |

FAHRENHEIT TO CENTIGRADE

| °F. | °C. | °F. | °C. | °F. | °C. | °F. | °C. | °F. | °C. |
|---|---|---|---|---|---|---|---|---|---|
| 28 | −2. 2 | 41 | 5. 0 | 54 | 12. 2 | 67 | 19. 4 | 80 | 26. 7 |
| 29 | −1. 7 | 42 | 5. 6 | 55 | 12. 8 | 68 | 20. 0 | 81 | 27. 2 |
| 30 | −1. 1 | 43 | 6. 1 | 56 | 13. 3 | 69 | 20. 6 | 82 | 27. 8 |
| 31 | −0. 6 | 44 | 6. 7 | 57 | 13. 9 | 70 | 21. 1 | 83 | 28. 3 |
| 32 | 0. 0 | 45 | 7. 2 | 58 | 14. 4 | 71 | 21. 7 | 84 | 28. 9 |
| 33 | +0. 6 | 46 | 7. 8 | 59 | 15. 0 | 72 | 22. 2 | 85 | 29. 4 |
| 34 | 1. 1 | 47 | 8. 3 | 60 | 15. 6 | 73 | 22. 8 | 86 | 30. 0 |
| 35 | 1. 7 | 48 | 8. 9 | 61 | 16. 1 | 74 | 23. 3 | 87 | 30. 6 |
| 36 | 2. 2 | 49 | 9. 4 | 62 | 16. 7 | 75 | 23. 9 | 88 | 31. 1 |
| 37 | 2. 8 | 50 | 10. 0 | 63 | 17. 2 | 76 | 24. 4 | 89 | 31. 7 |
| 38 | 3. 3 | 51 | 10. 6 | 64 | 17. 8 | 77 | 25. 0 | 90 | 32. 2 |
| 39 | 3. 9 | 52 | 11. 1 | 65 | 18. 3 | 78 | 25. 6 | | |
| 40 | 4. 4 | 53 | 11. 7 | 66 | 18. 9 | 79 | 26. 1 | | |

TABLE 40.—*Map scales and equivalents*

(The term "scale" as used in the formulas at the bottom of the table is the reciprocal of the fractional scale.)

| Fractional scale | Feet per in. | In. per 1,000 ft. | Inches per stat. mile | Stat. miles per in. | Meters per in. | Acres per sq. in. | Sq. in. per acre | Sq. stat. mi. per sq. inch |
|---|---|---|---|---|---|---|---|---|
| 1:500 | 41.667 | 24.00 | 126.72 | 0.008 | 12.700 | 0.0399 | 25.091 | 0.00006 |
| 1:600 | 50.00 | 20.00 | 105.60 | 0.009 | 15.240 | 0.0574 | 17.424 | 0.00009 |
| 1:1,000 | 83.333 | 12.00 | 63.36 | 0.016 | 25.400 | 0.1594 | 6.274 | 0.00025 |
| 1:1,200 | 100.00 | 10.00 | 52.80 | 0.019 | 30.480 | 0.2296 | 4.356 | 0.00036 |
| 1:1,500 | 125.00 | 8.00 | 42.24 | 0.024 | 38.100 | 0.3587 | 2.788 | 0.00056 |
| 1:2,000 | 166.667 | 6.00 | 31.68 | 0.032 | 50.800 | 0.6377 | 1.568 | 0.00100 |
| 1:2,400 | 200.00 | 5.00 | 26.40 | 0.038 | 60.960 | 0.9183 | 1.089 | 0.0014 |
| 1:2,500 | 208.333 | 4.80 | 25.344 | 0.039 | 63.500 | 0.9964 | 1.004 | 0.0016 |
| 1:3,000 | 250.00 | 4.00 | 21.12 | 0.047 | 76.200 | 1.4348 | 0.697 | 0.0022 |
| 1:3,600 | 300.00 | 3.333 | 17.60 | 0.057 | 91.440 | 2.0661 | 0.484 | 0.0032 |
| 1:4,000 | 333.333 | 3.00 | 15.84 | 0.063 | 101.600 | 2.5508 | 0.392 | 0.0040 |
| 1:4,800 | 400.00 | 2.50 | 13.20 | 0.076 | 121.920 | 3.6731 | 0.272 | 0.0057 |
| 1:5,000 | 416.667 | 2.40 | 12.672 | 0.079 | 127.000 | 3.9856 | 0.251 | 0.0062 |
| 1:6,000 | 500.00 | 2.00 | 10.56 | 0.095 | 152.400 | 5.7392 | 0.174 | 0.0090 |
| 1:7,000 | 583.333 | 1.714 | 9.051 | 0.110 | 177.800 | 7.8117 | 0.128 | 0.0122 |
| 1:7,200 | 600.00 | 1.667 | 8.80 | 0.114 | 182.880 | 8.2645 | 0.121 | 0.0129 |
| 1:7,920 | 660.00 | 1.515 | 8.00 | 0.125 | 201.168 | 10.00 | 0.100 | 0.0156 |
| 1:8,000 | 666.667 | 1.500 | 7.92 | 0.126 | 203.200 | 10.203 | 0.098 | 0.0159 |
| 1:8,400 | 700.00 | 1.429 | 7.543 | 0.133 | 213.360 | 11.249 | 0.089 | 0.0176 |
| 1:9,000 | 750.00 | 1.333 | 7.04 | 0.142 | 228.600 | 12.913 | 0.077 | 0.0202 |
| 1:9,600 | 800.00 | 1.250 | 6.60 | 0.152 | 243.840 | 14.692 | 0.068 | 0.0230 |
| 1:10,000 | 833.333 | 1.200 | 6.336 | 0.158 | 254.000 | 15.942 | 0.063 | 0.0249 |
| 1:10,800 | 900.00 | 1.111 | 5.867 | 0.170 | 274.321 | 18.595 | 0.054 | 0.0291 |
| 1:12,000 | 1,000.00 | 1.0 | 5.280 | 0.189 | 304.801 | 22.957 | 0.044 | 0.0359 |
| 1:13,200 | 1,100.00 | 0.909 | 4.800 | 0.208 | 335.281 | 27.778 | 0.036 | 0.0434 |
| 1:14,400 | 1,200.00 | 0.833 | 4.400 | 0.227 | 365.761 | 33.058 | 0.030 | 0.0517 |
| 1:15,000 | 1,250.00 | 0.80 | 4.224 | 0.237 | 381.001 | 35.870 | 0.028 | 0.0560 |
| 1:15,600 | 1,300.00 | 0.769 | 4.062 | 0.246 | 396.241 | 38.797 | 0.026 | 0.0606 |
| 1:15,840 | 1,320.00 | 0.758 | 4.00 | 0.250 | 402.337 | 40.000 | 0.025 | 0.0625 |
| 1:16,000 | 1,333.333 | 0.750 | 3.96 | 0.253 | 406.401 | 40.812 | 0.025 | 0.0638 |
| 1:16,800 | 1,400.00 | 0.714 | 3.771 | 0.265 | 426.721 | 44.995 | 0.022 | 0.0703 |
| 1:18,000 | 1,500.00 | 0.667 | 3.52 | 0.284 | 457.201 | 51.653 | 0.019 | 0.0807 |
| 1:19,200 | 1,600.00 | 0.625 | 3.30 | 0.303 | 487.681 | 58.770 | 0.017 | 0.0918 |
| 1:20,000 | 1,666.667 | 0.60 | 3.168 | 0.316 | 508.001 | 63.769 | 0.016 | 0.0996 |
| 1:20,400 | 1,700.00 | 0.588 | 3.106 | 0.322 | 518.161 | 66.345 | 0.015 | 0.1037 |
| 1:21,120 | 1,760.00 | 0.568 | 3.00 | 0.333 | 536.449 | 71.111 | 0.014 | 0.1111 |
| 1:21,600 | 1,800.00 | 0.556 | 2.933 | 0.341 | 548.641 | 74.380 | 0.013 | 0.1162 |
| 1:22,800 | 1,900.00 | 0.526 | 2.779 | 0.360 | 579.121 | 82.874 | 0.012 | 0.1295 |
| 1:24,000 | 2,000.00 | 0.50 | 2.640 | 0.379 | 609.601 | 91.827 | 0.011 | 0.1435 |
| 1:25,000 | 2,083.333 | 0.480 | 2.534 | 0.395 | 635.001 | 99.639 | 0.010 | 0.1557 |
| 1:31,680 | 2,640.00 | 0.379 | 2.000 | 0.500 | 804.674 | 160.000 | 0.006 | 0.2500 |
| 1:40,000 | 3,333.333 | 0.30 | 1.584 | 0.631 | 1,016.002 | 255.076 | 0.004 | 0.3986 |
| 1:48,000 | 4,000.00 | 0.250 | 1.320 | 0.758 | 1,219.202 | 367.309 | 0.003 | 0.5739 |
| 1:62,500 | 5,208.333 | 0.192 | 1.014 | 0.986 | 1,587.503 | 622.744 | 0.0016 | 0.9730 |
| 1:63,360 | 5,280.00 | 0.189 | 1.000 | 1.000 | 1,609.347 | 640.00 | 0.0016 | 1.0000 |
| 1:80,000 | 6,666.667 | 0.150 | 0.792 | 1.263 | 2,032.004 | 1,020.304 | 0.0010 | 1.5942 |
| 1:96,000 | 8,000.00 | 0.125 | 0.660 | 1.515 | 2,438.405 | 1,469.24 | 0.0007 | 2.2957 |
| 1:120,000 | 10,000.00 | 0.10 | 0.528 | 1.894 | 3,048.006 | 2,295.684 | 0.0004 | 3.5870 |
| 1:125,000 | 10,416.667 | 0.096 | 0.507 | 1.973 | 3,175.006 | 2,490.98 | 0.0004 | 3.8922 |
| 1:126,720 | 10,560.00 | 0.095 | 0.500 | 2.00 | 3,218.694 | 2,560.00 | 0.0004 | 4.00 |
| 1:250,000 | 20,833.333 | 0.048 | 0.253 | 3.946 | 6,350.012 | 9,963.907 | 0.0001 | 15.5686 |
| 1:253,440 | 21,120.00 | 0.047 | 0.250 | 4.00 | 6,437.389 | 10,240.00 | 0.0001 | 16.00 |
| 1:500,000 | 41,666.667 | 0.024 | 0.127 | 7.891 | 12,700.025 | 39,855.627 | 0.$\underline{4}$25 | 62.2744 |
| 1:1,000,000 | 83,333.333 | 0.012 | 0.063 | 15.783 | 25,400.050 | 159,422.508 | 0.$\underline{5}$62 | 249.0977 |
| Formulas | $\frac{\text{Scale}}{12}$ | $\frac{12,000}{\text{Scale}}$ | $\frac{63,360}{\text{Scale}}$ | $\frac{\text{Scale}}{63,360}$ | Ft. per in. $\times$ 0.3048006 | $\frac{(\text{Scale})^2}{43,560 \times 144}$ | $\frac{43,560 \times 144}{(\text{Scale})^2}$ | $\frac{(\text{Ft. per in.})^2}{(5,280)^2}$ |

## 964. Trigonometric Functions for Circle-Sheet Construction

For use in constructing *circle* sheets (see section **37**) a table of natural half-cosecants and half-cotangents to four places is given. The values are given for each 10 minutes from 1° to 20°, for each half degree from 20° to 50°, and for each degree from 50° to 90°.

Table 41.—*Natural half-cosecants and half-cotangents*

| Angle | ½ cosec | ½ cot | Angle | ½ cosec | ½ cot | Angle | ½ cosec | ½ cot |
|---|---|---|---|---|---|---|---|---|
| ° ′ | | | ° ′ | | | ° ′ | | |
| 1 00 | 28. 6493 | 28. 6450 | 8 00 | 3. 5926 | 3. 5577 | 15 00 | 1. 9319 | 1. 8660 |
| 10 | 24. 5570 | 24. 5519 | 10 | . 5198 | . 4841 | 10 | . 9111 | . 8445 |
| 20 | 21. 4879 | 21. 4820 | 20 | . 4499 | . 4135 | 20 | . 8908 | . 8235 |
| 30 | 19. 1008 | 19. 0942 | 30 | . 3827 | . 3456 | 30 | . 8710 | . 8029 |
| 40 | 17. 1912 | 17. 1839 | 40 | . 3182 | . 2803 | 40 | . 8516 | . 7828 |
| 50 | 15. 6288 | 15. 6208 | 50 | . 2560 | . 2174 | 50 | . 8326 | . 7630 |
| 2 00 | 14. 3269 | 14. 3181 | 9 00 | 3. 1962 | 3. 1569 | 16 00 | 1. 8140 | 1. 7437 |
| 10 | 13. 2253 | 13. 2158 | 10 | . 1386 | . 0985 | 10 | . 7958 | . 7248 |
| 20 | 12. 2811 | 12. 2709 | 20 | . 0830 | . 0422 | 20 | . 7779 | . 7062 |
| 30 | 11. 4628 | 11. 4519 | 30 | . 0294 | 2. 9879 | 30 | . 7605 | . 6880 |
| 40 | 10. 7468 | 10. 7352 | 40 | 2. 9777 | . 9354 | 40 | . 7434 | . 6701 |
| 50 | 10. 1151 | 10. 1028 | 50 | . 9277 | . 8847 | 50 | . 7266 | . 6526 |
| 3 00 | 9. 5537 | 9. 5406 | 10 00 | 2. 8794 | 2. 8356 | 17 00 | 1. 7102 | 1. 6354 |
| 10 | 9. 0513 | 9. 0375 | 10 | . 8327 | . 7882 | 10 | . 6940 | . 6186 |
| 20 | 8. 5992 | 8. 5847 | 20 | . 7875 | . 7423 | 20 | . 6782 | . 6020 |
| 30 | 8. 1902 | 8. 1749 | 30 | . 7437 | . 6978 | 30 | . 6628 | . 5858 |
| 40 | 7. 8184 | 7. 8024 | 40 | . 7013 | . 6546 | 40 | . 6476 | . 5699 |
| 50 | 7. 4789 | 7. 4622 | 50 | . 6602 | . 6128 | 50 | . 6327 | . 5542 |
| 4 00 | 7. 1678 | 7. 1503 | 11 00 | 2. 6204 | 2. 5723 | 18 00 | 1. 6180 | 1. 5388 |
| 10 | 6. 8816 | 6. 8634 | 10 | . 5818 | . 5329 | 10 | . 6037 | . 5237 |
| 20 | . 6174 | . 5984 | 20 | . 5443 | . 4947 | 20 | . 5896 | . 5089 |
| 30 | . 3727 | . 3531 | 30 | . 5079 | . 4576 | 30 | . 5758 | . 4943 |
| 40 | . 1456 | . 1252 | 40 | . 4726 | . 4215 | 40 | . 5622 | . 4800 |
| 50 | 5. 9342 | 5. 9131 | 50 | . 4382 | . 3864 | 50 | . 5489 | . 4659 |
| 5 00 | 5. 7369 | 5. 7150 | 12 00 | 2. 4049 | 2. 3523 | 19 00 | 1. 5358 | 1. 4521 |
| 10 | . 5523 | . 5297 | 10 | . 3724 | . 3191 | 10 | . 5229 | . 4385 |
| 20 | . 3792 | . 3560 | 20 | . 3408 | . 2868 | 20 | . 5103 | . 4251 |
| 30 | . 2167 | . 1927 | 30 | . 3101 | . 2554 | 30 | . 4979 | . 4120 |
| 40 | . 0638 | . 0390 | 40 | . 2802 | . 2247 | 40 | . 4857 | . 3990 |
| 50 | 4. 9196 | 4. 8941 | 50 | . 2511 | . 1948 | 50 | . 4737 | . 3863 |
| 6 00 | 4. 7834 | 4. 7572 | 13 00 | 2. 2227 | 2. 1657 | 20 00 | 1. 4619 | 1. 3737 |
| 10 | . 6546 | . 6277 | 10 | . 1951 | . 1374 | 30 | . 4277 | . 3373 |
| 20 | . 5326 | . 5049 | 20 | . 1681 | . 1097 | 21 00 | . 3952 | . 3025 |
| 30 | . 4168 | . 3884 | 30 | . 1418 | . 0826 | 30 | . 3643 | . 2693 |
| 40 | . 3069 | . 2778 | 40 | . 1162 | . 0563 | 22 00 | . 3347 | . 2375 |
| 50 | . 2023 | . 1725 | 50 | . 0912 | . 0305 | 30 | . 3066 | . 2071 |
| | | | | | | 23 00 | . 2797 | . 1779 |
| 7 00 | 4. 1028 | 4. 0722 | 14 00 | 2. 0668 | 2. 0054 | 30 | . 2539 | . 1499 |
| 10 | . 0078 | 3. 9765 | 10 | . 0430 | 1. 9808 | 24 00 | . 2293 | . 1230 |
| 20 | 3. 9172 | . 8852 | 20 | . 0197 | . 9568 | 30 | . 2057 | . 0971 |
| 30 | . 8306 | . 7979 | 30 | 1. 9970 | . 9334 | | | |
| 40 | . 7479 | . 7144 | 40 | . 9748 | . 9104 | 25 00 | 1. 1831 | 1. 0723 |
| 50 | . 6686 | . 6344 | 50 | . 9531 | . 8880 | 30 | . 1614 | . 0483 |

TABLE 41.—*Natural half-cosecants and half-cotangents*—Continued

| Angle | ½ cosec | ½ cot | Angle | ½ cosec | ½ cot | Angle | ½ cosec | ½ cot |
|---|---|---|---|---|---|---|---|---|
| ° ′ | | | ° ′ | | | ° ′ | | |
| 26 00 | 1. 1406 | 1. 0252 | 41 30 | 0. 7546 | 0. 5651 | 63 00 | 0. 5612 | 0. 2548 |
| 30 | . 1206 | . 0028 | 42 00 | . 7472 | . 5553 | 64 00 | . 5563 | . 2439 |
| 27 00 | . 1013 | 0. 9813 | 30 | . 7401 | . 5457 | | | |
| 30 | . 0828 | . 9605 | 43 00 | . 7331 | . 5362 | 65 00 | . 5517 | . 2332 |
| 28 00 | . 0650 | . 9404 | 30 | . 7264 | . 5269 | 66 00 | . 5473 | . 2226 |
| 30 | . 0479 | . 9209 | 44 00 | . 7198 | . 5178 | 67 00 | . 5432 | . 2122 |
| 29 00 | . 0313 | . 9020 | 30 | . 7134 | . 5088 | 68 00 | . 5393 | . 2020 |
| 30 | . 0154 | . 8837 | | | | 69 00 | . 5356 | . 1919 |
| | | | 45 00 | 0. 7071 | 0. 5000 | | | |
| 30 00 | 1. 0000 | 0. 8660 | 30 | . 7010 | . 4913 | 70 00 | 0. 5321 | 0. 1820 |
| 30 | 0. 9851 | . 8488 | 46 00 | . 6951 | . 4828 | 71 00 | . 5288 | . 1722 |
| 31 00 | . 9708 | . 8321 | 30 | . 6893 | . 4745 | 72 00 | . 5257 | . 1625 |
| 30 | . 9569 | . 8159 | 47 00 | . 6837 | . 4663 | 73 00 | . 5228 | . 1529 |
| 32 00 | . 9435 | . 8002 | 30 | . 6782 | . 4582 | 74 00 | . 5201 | . 1434 |
| 30 | . 9306 | . 7848 | 48 00 | . 6728 | . 4502 | | | |
| 33 00 | . 9180 | . 7699 | 30 | . 6676 | . 4424 | 75 00 | . 5176 | . 1340 |
| 30 | . 9059 | . 7554 | 49 00 | . 6625 | . 4346 | 76 00 | . 5153 | . 1247 |
| 34 00 | . 8941 | . 7413 | 30 | . 6575 | . 4270 | 77 00 | . 5132 | . 1154 |
| 30 | . 8828 | . 7275 | | | | 78 00 | . 5112 | . 1063 |
| | | | 50 00 | 0. 6527 | 0. 4195 | 79 00 | . 5094 | . 0972 |
| 35 00 | 0. 8717 | 0. 7141 | 51 00 | . 6434 | . 4049 | | | |
| 30 | . 8610 | . 7010 | 52 00 | . 6345 | . 3906 | 80 00 | 0. 5077 | 0. 0882 |
| 36 00 | . 8507 | . 6882 | 53 00 | . 6261 | . 3768 | 81 00 | . 5062 | . 0792 |
| 30 | . 8406 | . 6757 | 54 00 | . 6180 | . 3633 | 82 00 | . 5049 | . 0703 |
| 37 00 | . 8308 | . 6635 | | | | 83 00 | . 5038 | . 0614 |
| 30 | . 8213 | . 6516 | 55 00 | . 6104 | . 3501 | 84 00 | . 5028 | . 0526 |
| 38 00 | . 8121 | . 6400 | 56 00 | 0. 6031 | 0. 3373 | | | |
| 30 | . 8032 | . 6286 | 57 00 | . 5962 | . 3247 | 85 00 | . 5019 | . 0437 |
| 39 00 | . 7945 | . 6174 | 58 00 | . 5896 | . 3124 | 86 00 | . 5012 | . 0350 |
| 30 | . 7861 | . 6065 | 59 00 | . 5833 | . 3004 | 87 00 | . 5007 | . 0262 |
| | | | | | | 88 00 | . 5003 | . 0175 |
| 40 00 | 0. 7779 | 0. 5959 | 60 00 | 0. 5774 | 0. 2887 | 89 00 | . 5001 | . 0087 |
| 30 | . 7699 | . 5854 | 61 00 | . 5717 | . 2772 | | | |
| 41 00 | . 7621 | . 5752 | 62 00 | . 5663 | . 2659 | 90 00 | 0. 5000 | 0. 000 |

## 965. THREE-LETTER STATION NAMES

Control stations to which three-letter names are to be assigned in accordance with **2151** and **2152** shall be named from the list in table 42. Duplication of station names on one survey sheet is to be avoided, but there is no objection to such a duplication on adjacent sheets.

TABLE 42.—*Three-letter station names*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Abe | Cab | Ego | Gem | Jap | Man | Oil | Rip | Tub |
| Ace | Cam | Elf | Geo | Jar | Mar | Old | Rot | |
| Act | Car | Elm | Get | Jay | Maw | Ora | Roy | Use |
| Add | Cat | Emo | Gig | Jaw | Max | Orb | Rub | |
| Ado | Caw | End | Gin | Jib | Met | Out | Rue | Val |
| Ago | Cod | Eon | Gob | Jim | Mid | Owl | Rum | Van |
| Aha | Con | Era | Got | Job | Moo | | | Vet |
| Aim | Coo | Erg | Gum | Joe | Mop | Pad | Sad | Vex |
| Alp | Cop | Est | Gus | Joy | Mug | Pal | Sag | Via |
| Amp | Cow | Eva | Guy | Jug | Mum | Par | Sal | Vim |
| Amy | Cry | | | Jut | | Paw | Sam | |
| Ann | Cue | Far | Hag | | Nat | Peg | Sax | Wad |
| Ant | Cur | Fat | Hat | Ked | Nay | Pep | Set | Wag |
| Apt | Cut | Fed | Hem | Ken | Ned | Pet | Sic | Wan |
| Arm | | Few | Her | Key | Neo | Pie | Sip | War |
| Art | Daw | Fez | Hex | Kid | New | Pin | Sir | Was |
| Ask | Day | Fig | Hid | Kim | Nig | Pit | Sis | Wax |
| Ave | Deb | Fin | His | | Nil | Pix | She | Wed |
| Axe | Dif | Fit | Hod | Lad | Nip | Ply | Ski | Wee |
| Azo | Dim | Fix | Hoe | Lam | Nit | Poi | Sky | Wen |
| | Dip | Fly | Hon | Lax | Nix | Pot | Sly | Who |
| Bag | Dix | Foe | Hop | Lay | Nod | Pro | Sol | Why |
| Bah | Doc | Fog | How | Leg | Non | Pug | Sop | Wig |
| Bat | Dog | Fop | Hub | Leo | Nor | Pup | Sow | Win |
| Bed | Don | For | Hug | Let | Now | Put | Sox | Wit |
| Bib | Dot | Fox | Hum | Lip | Nub | | Sty | Woo |
| Big | Dud | Fro | Hut | Liz | Nul | Quo | Sub | |
| Boa | Dun | Fry | | Log | Nut | | Sue | Yak |
| Bob | Duo | Fun | Ice | Lop | Nux | Rag | | Yam |
| Bon | | | Ida | Low | | Ram | Tan | Yea |
| Box | Ear | Gad | Ion | Lug | Oak | Rat | Tap | Yes |
| Bum | Eat | Gag | Irk | Lux | Obi | Rev | Tax | Yet |
| Bus | Ebb | Gal | Its | | Odd | Rig | Thy | |
| But | Eel | Gam | Ivy | Mag | Off | Rim | Tom | Zag |
| | Egg | Gas | | Mal | Ohm | Rio | Toy | Zig |
| | | | | | | | Try | Zoo |

## 97. SYMBOLS AND ABBREVIATIONS FOR NAUTICAL CHARTS

The standard symbols and abbreviations which have been approved for use on nautical charts published by the Coast and Geodetic Survey are reproduced as figure 189 on 11 consecutive pages, and a section of a finished nautical chart is reproduced as figure 190. The same symbols and abbreviations are to be used on hydrographic survey sheets, except as specifically mentioned in the text of chapter 7 and as shown in figures 169 and 171. For example, depth curves on hydrographic sheets are drawn in distinctive colors and not symbolized as on the published charts.

PAGE 888

NAUTICAL CHART

# SYMBOLS AND ABBREVIATIONS

USED BY THE

## COAST AND GEODETIC SURVEY

## General Remarks

*(1)* *Soundings are expressed in feet or fathoms as stated in the title of the chart.*

*(2)* *The visibility of lights is in nautical miles for an observer's eye 15 feet above water level.*

*(3)* N.A. 1927 *at the upper right-hand corner of the chart is an abbreviation for "North American datum of 1927".*

*(4)* *Longitudes are referred to the Meridian of Greenwich.*

*(5)* *The coastline is the line of mean high water, except along mangrove and marsh.*

*(6)* *Nautical charts, unless otherwise noted in the title, are constructed on the Mercator projection, and are computed for the middle latitude of the chart or the middle latitude of a series of charts.*

*(7)* *Heights of land and conspicuous objects are given in feet above mean high water, unless otherwise stated in the title of the chart. Elevations of rocks, lighthouses, contours, and hills, are in feet above mean high water. Underlined elevations of mountain peaks are in feet above mean sea level.*

*(8)* *Dredged channels are shown by limiting dash lines with the depth, month, and year of latest examination.*

*(9)* *Explanation of marginal notes may be found in the Coast Pilot, and in the Chart Catalog.*

*(10)* *The use of capitals and the style of lettering given on this sheet is not always rigidly adhered to on the charts.*

*(11)* *Caution note:*

CAUTION

Temporary changes affecting
Lights, Buoys and Day Beacons

Aids which have been destroyed or removed, but which will be reestablished and are temporarily replaced by aids of different characteristics, are indicated in color by the following abbreviations.

| | |
|---|---|
| D | *Destroyed, to be reestablished.* |
| T R B | *Temporarily replaced by a red buoy.* |
| T B B | *Temporarily replaced by a black buoy.* |
| T F B | *Temporarily replaced by a fixed white lighted buoy.* |
| T F R B | *Temporarily replaced by a fixed red lighted buoy.* |
| T FL B | *Temporarily replaced by a flashing white lighted buoy.* |
| T FL R B | *Temporarily replaced by a flashing red lighted buoy.* |
| T FL G B | *Temporarily replaced by a flashing green lighted buoy.* |

*(12)* *The use of colors is optional and some of them may be changed for special reasons.*

*Symbols and abbreviations are numbered in accordance with a standard form proposed by the International Hydrographic Bureau.*

*Vertical figures indicate that the symbol or abbreviation is in accordance with the I. H. B. standard.*

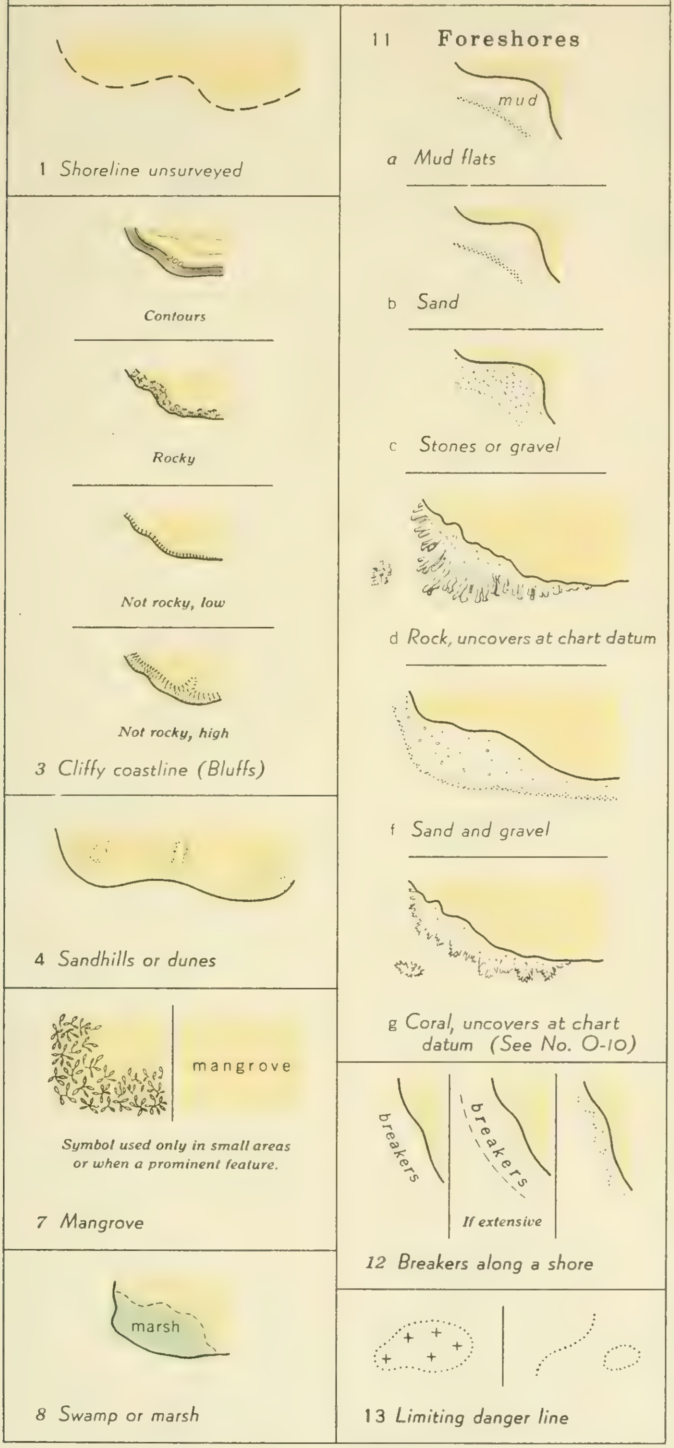
*Symbols or abbreviations which differ from those of the I. H. B., or which do not appear on the standard are indicated by slant figures.*

*Figures in parentheses indicate that the symbol or abbreviation is in addition to those shown on the standard.*

*No periods are used after abbreviations placed in water areas.*

FIGURE 189. — Symbols and abbreviations for nautical charts (part I).

## A. The Coastline

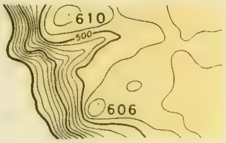



## B. Coast Features

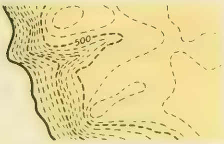
| | | |
|---|---|---|
| 2 | *B.* | *Bay* |
| (2a) | *B.* | *Bayou* |
| 5 | *Cr.* | *Creek* |
| 5a | *C.* | *Cove* |
| 7 | *Str.* | *Strait* |
| 8 | *Sd.* | *Sound* |
| 9 | *Pass.* | *Passage, Pass* |
| 10 | *Chan.* | *Channel* |
| 11 | *Entr.* | *Entrance* |
| 15 | *Anch.* | *Anchorage* |
| 16 | *Hbr.* | *Harbor* |
| 18 | I. | *Island* |
| 19 | It. | *Islet* |
| 21 | Pena. | *Peninsula* |
| 22 | C. | *Cape* |
| 24 | Hd. | *Head* |
| 25 | Pt. | *Point* |
| 26 | Mt. | *Mountain*<br>*Mount* |
| 27 | R. | *Range* |
| 29 | Pk. | *Peak* |
| 30 | Vol. | *Volcano* |
| (33) | *St.* | *Stream* |
| (34) | *R.* | *River* |
| (35) | *Slu.* | *Slough* |
| (36) | *Ln.* | *Lagoon* |
| (37) | *Thoro.* | *Thorofare* |
| (38) | *L.* | *Lake* |
| (39) | *P.* | *Pond, Port* |

FIGURE 189. — Symbols and abbreviations for nautical charts (part II).

## C. The Land

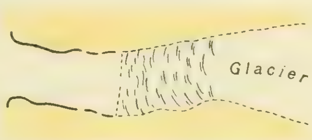



1 *Contours or form lines*




*(a) Contours or form lines, estimated*


2 *Hachures*




3 *Glacier*

○ TREE

*A conspicuous clump or single tree of any kind useful as a landmark.*

5 *Isolated trees*

wooded

9 *Deciduous woodland (woodland of any kind)*

2050 (tree tops)

*(11) Elevation of top of trees*

## D. Control Points

| | | | |
|---|---|---|---|
| 1 | △ | | *Triangulation point* |
| 3 | ·256 | | *Summit of height (Peak) (when not a landmark)* |
| *(a)* | 256 | | *Peak, accentuated by contours* |
| *(b)* | 256 | | *Peak, accentuated by hachures* |
| *(c)* | | | *Peak, when elevation has not been determined* |
| *(d)* | ○256 | | *Peak, when a landmark* |
| *4* | ⊕ | Obs. Spot | *Observation spot* |
| *5* | | B.M. | *Bench mark* |
| 6 | ∘ | See View | *View point* |
| *(9)* | | Astr. | *Astronomical* |
| *(10)* | | Tri. | *Triangulation* |
| *(11)* | | U. S. E. | *United States Engineers* |

## E. Units

| | | |
|---|---|---|
| *1* | hr. | *hour* |
| 2 | min. | *minute* |
| *3* | sec. | *second* |
| *4* | m. | *meter* |
| 5 | km. | *kilometer* |
| 6 | in. | *inch* |
| 7 | ft. | *foot* |
| 8 | yd. | *yard* |
| 9 | fm. | *fathom* |
| 11 | m. | *nautical mile* |
| *12* | kn. | *knot* |
| 13 | lat. | *latitude* |
| 14 | long. | *longitude* |
| *17* | cor. | *correction* |
| *(18)* | alt. | *altitude* |
| *(19)* | ht. | *height* |

FIGURE 189. — Symbols and abbreviations for nautical charts (part III).

# F. Adjectives

**and other abbreviations**

| | | |
|---|---|---|
| 1 | *gt.* | *great* |
| 3 | *lrg.* | *large* |
| 4 | *sml.* | *small* |
| 7 | *mid.* | *middle* |
| 9 | *anc.* | *ancient* |
| 12 | *conspic.* | *conspicuous* |
| 16 | *dist.* | *distant* |
| 17 | *abt.* | *about* |
| (19) | *aband.* | *abandoned* |
| (20) | *extr.* | *extreme* |
| (21) | *concr.* | *concrete* |
| (22) | *bet.* | *between* |
| (23) | *estab.* | *established* |
| (24) | *exper.* | *experimental* |
| (25) | *discontd.* | *discontinued* |
| (26) | *fl.* | *flood* |
| (27) | *mod.* | *moderate* |
| (28) | *maintd.* | *maintained* |
| (29) | *elec.* | *electric* |
| (30) | *priv.* | *private, privately* |
| (31) | *prom.* | *prominent* |
| (32) | *std.* | *standard* |
| (33) | *subm.* | *submerged* |
| (34) | *approx.* | *approximate* |
| (35) | cor. | *corner* |
| (36) | Cl. | *clearance* |
| (37) | No. | *number* |

# G. Harbors

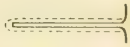
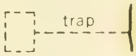
| | | | |
|---|---|---|---|
| 1 |  | *Anch.* | *Anchorage, large vessels (see No. P-12)* |
| 2 |  | *Anch.* | *Anchorage, small vessels* |
| 3 | | ***Hbr.*** | *Harbor* |
| 6 |  | Bkwr. | *breakwater* |
| 8 |  | | *jetty (partly below M H W )* |
| (8a) |  | | *jetty (small scale)* |
| 9 |  | | *pier* |
| 11 |  | | *groin (partly below M H W )* |
| 12 | *Anchorage prohibited* | | *Anchorage prohibited* |
| 13 | *spoil grd.* | | *spoil ground* |
| 14 |   | | *fish traps (actual shape charted)* |
| (14a) |  | fsh. stk. | *fishing stakes when dangerous* |
| 16 | | Ldg. | *landing place* |
| 18 |  | Whf. | *wharf* |
| 21 |  | dol. | *dolphin* |
| 26 | | Quar. | *Quarantine* |
| 29 | | Cus. Ho. | *Customhouse* |
| 33 | | B. Hbr. | *Boat Harbor* |
| 35 |  | | *dock* |
| 36 |  | | *dry dock (actual shape shown on large scale charts)* |
| 37 |  | | *floating dock (actual shape shown on large scale charts)* |
| 39 |  | | *patent slip (marine railway)* |
| 40 |   | | *lock* |
| 45 | | Obsy. | *Observatory* |

FIGURE 189. — Symbols and abbreviations for nautical charts (part IV).

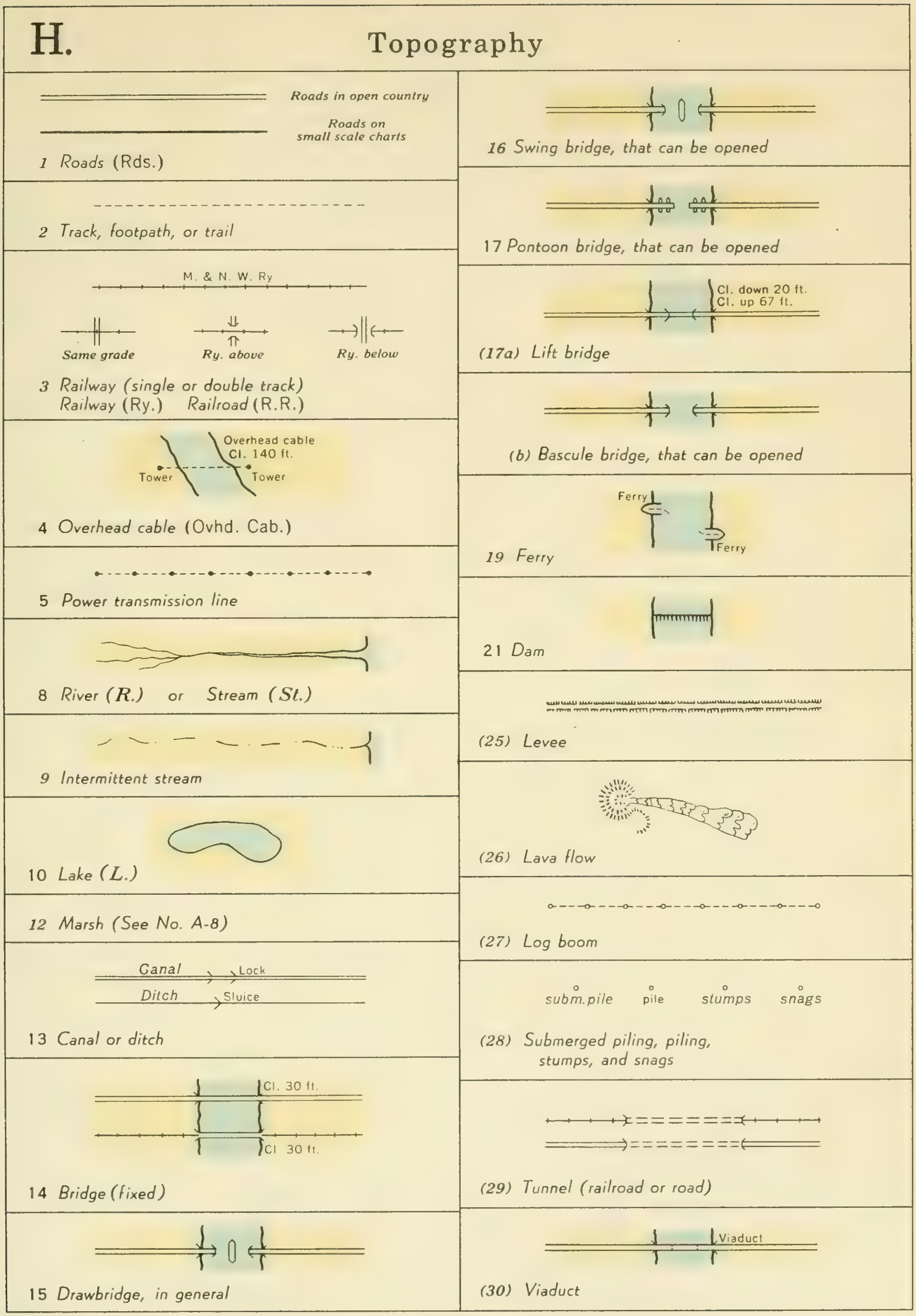
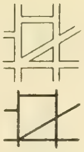
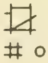



FIGURE 189. – Symbols and abbreviations for nautical charts (part V).

# I. Buildings

*When the buildings are prominent, they may be shown by landmark symbol with descriptive note. (See No. L-63)*

| No. | Symbol | Abbreviation | Meaning |
|---|---|---|---|
| *1* |  | | *City or town (large scale)* |
| *(1a)* |  | | *City or town (small scale)* |
| 3 |  | **Vil.** | *Village* |
| 4 | | Cas. | *Castle* |
| 5 |  | Ho. | *House* |
| *8* |  | Ch. | *Church* |
| *18* |  | Cem. | *Cemetery* |
| *19* |  | | *Fort (actual shape charted)* |
| *23*<br>*24* |  | | *Airplane landing field*<br>*Airport (large scale)* |
| *(24a)*<br>*(24b)* |  | | *Small scale*<br>*Airport (military)*<br>*Airport (commercial)* |
| *26* | First St. | | *Street* |
| *(26a)* | Main Ave. | | *Avenue* |
| 27 | | Tel. | *Telegraph* |
| 29 | | P.O. | *Post Office* |

| No. | Symbol | Abbreviation | Meaning |
|---|---|---|---|
| 30 | | Govt. | *Government* |
| *32* | | Hosp. | *Hospital* |
| 34 | | Magz. | *Magazine* |
| *35* | ○ MONU | | *Monument* |
| *36* | ○ CUP | | *Cupola* |
| *37* | | elev. | *elevation*<br>*elevator*<br>*elevated* |
| *40* |  | | *Ruins* |
| *41* | ○ TR | | *Tower* |
| *(42a)* | ○ WINDMILL | | *Windmill when landmark* |
| *44* | ○ CHY | | *Chimney* |
| *44a* | ○ STACK | | *Stack* |
| 46 |  | | *Oil tank* |
| *47* |  | Facty. | *Factory* |
| *(56)* | ○ GAB | | *Gable* |
| *(57)* |  | Sch. | *School* |
| *(58)* | | H.S. | *High School* |
| *(59)* | | Univ. | *University* |
| *(60)* | | Inst. | *Institute* |
| *(61)* | | Co. | *Company* |
| *(62)* | | Corp. | *Corporation* |
| *(63)* | | Cap. | *Capitol* |
| *(64)* | | C.H. | *Courthouse* |
| *(65)* | | Cath. | *Cathedral* |
| *(66)* | | Bldg. | *Building* |
| *(67)* | | Pav. | *Pavilion* |

FIGURE 189. — Symbols and abbreviations for nautical charts (part VI).

# J. Miscellaneous Stations

| | | |
|---|---|---|
| 2 | Sta. | Station |
| 3 | C. G | Coast Guard (similar to L. S. S.) |
| (3a) | C. G. WALLIS SANDS | When the building is a landmark |
| 6 | L. S S | Lifesaving Station (See No. J-3) |
| 8 | PIL. STA | Pilot Station |
| 9 | Sig. Sta. | Signal Station |
| 19 | F S | Flagstaff |
| (20) | W. B. SIG. STA. | Weather Bureau Signal Station |
| (21) | F P | Flagpole |
| (22) | F TR. | Flag tower |
| (23) | LOOK. TR. | Lookout tower |
| (24) | S PIPE | Standpipe |
| (25) | BELL | When on land |

# K. Lights

See General Remarks, note 11.

| | | |
|---|---|---|
| 1 | | Position of light |
| 2 | Lt. | Light |
| 3 | Lt. Ho. | Lighthouse |
| 4 | AERO | Aeronautical light |
| 5 | | Lighted beacon (Post light) |
| 6 | | Lightship |
| 7 | | Lighted buoy |
| 10 | REF. | Reflector |
| (17) | Priv. maintd. | Private light (maintained by private interests; to be used with caution) |
| 21 | F. | Fixed |
| 22 | Occ. | Occulting |
| 23 | FL. | Flashing |
| 24 | Qk. FL. | Quick flashing |
| (24a) | I. Qk. | Interrupted quick |
| 26 | Alt. | Alternating |
| 27 | Gp. Occ. | Group occulting |
| 28 | Gp. FL. | Group flashing |
| (28a) | S-L. | Short-long |
| 29 | F. FL. | Fixed and flashing |
| 30 | F. Gp. FL. | Fixed and group flashing |
| 31 | Rev. | Revolving |
| (39) | min. | minutes |
| (40) | sec. | seconds |
| 42 | ev. | every |
| 44 | vis. | visible |
| (44a) | m. | nautical mile |
| 47 | Gp. | group |
| 49 | SEC. | sector |
| 63 | Bu. | blue |
| 64 | G. | green |
| 66 | R. | red |
| 67 | W. | white |
| 68 | OBSC. | obscured |
| 69 | (U) | unwatched |
| 71 | Irreg. | irregular |
| 73 | Temp | temporary |
| 80 | Vert. | vertical |
| 81 | Hor. | horizontal |
| (82) | D. | destroyed |
| (83) | V. B. | vertical beam |
| (84) | Exper. | experimental |
| (85) | R. | range |
| (86) | AERO | aeronautical |

FIGURE 189. – Symbols and abbreviations for nautical charts (part VII).

## L. Buoys and Beacons

*On entering a channel from seaward, buoys on starboard side are red with even numbers, on port side black with odd numbers. Lighted buoys on starboard side of channel are red or white, on port side white or green. Mid-channel buoys have black and white vertical stripes. Obstruction buoys are green, or have red and black horizontal bands. The dot of the buoy symbol, and the small circle of the light vessel and mooring buoy symbols, indicate their positions.*

| | | |
|---|---|---|
| 1 | | Position of buoy |
| 2 | | Lighted buoy |
| 3 | BELL | Bell buoy |
| (3a) | GONG | Gong buoy |
| 4 | WHISTLE | Whistle buoy |
| 5 | C C | Can buoy |
| 6 | N N | Nun buoy |
| 8 | S S S | Spar buoy |
| (8a) | | Checkered buoy |
| 12 | | Lightship |
| 14 | | Fairway buoy (Mid-Channel) |
| 18 | | Junction buoy |
| 19 | | Isolated danger buoy |
| 20 | | Wreck or obstruction buoy |
| 22 | | Mooring buoy |
| 24 | Y Quar. | Quarantine buoy |
| (27) | | Fish trap buoy |
| (28) | | Anchorage buoy |
| (29) | Priv. maintd. | Maintained by private interests; to be used with caution |
| 31 | H. B.<br>H. S. | Horizontal bands<br>Horizontal stripes |
| 32 | V. S. | Vertical stripes |
| 33 | Chec. | checkered |
| 41 | W. | white |
| 42 | B. | black |
| 43 | R. | red |
| 44 | Y. | yellow |
| 45 | G. | green |
| (46) | Br. | brown |
| 52 | | Fixed beacons (unlighted daymarks) |
| (52a) | MARKER | Private aid to navigation |
| 53 | Bn. | Beacon (See No. L-52) |
| 63 | | Landmark |
| (64) | REF. | Reflector |

## M. Radio Stations

| | | |
|---|---|---|
| 1 | R S | Radio station |
| 3 | R Bn | Radiobeacon |
| 7 | R C | Radio Direction Finder Station |
| 9 | R. Tr. | Radio tower |
| (10) | R Tr. (WEAF) | Commercial broadcast |
| (11) | N R C | Naval Radio Direction Finder Station |

## N. Fog Signals

| | | |
|---|---|---|
| 1 | Fog Sig. | Fog Signal Station |
| 6 | SUB-BELL | Submarine fog bell (mechanical) |
| 7 | SUB-OSC. | Submarine oscillator |
| 8 | HORN | Nautophone |
| 9 | DIAPHONE | Diaphone |
| 11 | SIREN | Fog siren |
| 12 | HORN | Fog trumpet |
| 13 | HORN | Fog horn |
| 14 | BELL | Fog bell |
| 15 | WHISTLE | Fog whistle |
| 16 | HORN | Reed |
| 17 | GONG | Gong |
| (18) | D. F. S. | Distance Finding Sta. |

FIGURE 189. — Symbols and abbreviations for nautical charts (part VIII).

# O. Dangers

(27)

1 Rocks which do not cover; with their elevations above M H W

* uncovers 2 ft. at L W — *(2)

2 Rocks that cover and uncover, with heights in feet above chart datum

(3a) When rock of No. 2 is considered a danger to navigation

\+

(4a) Sunken rock below chart datum; depth not known

(4b) When rock of No. 4a is considered a danger to navigation

2 Rk

(4c) Shoal sounding on isolated rock replaces symbol

21 Rk — 21 Wk — 21 Obstr

(6a) Sunken danger with depth cleared by wire drag (Feet or fathoms)


10 Coral or rocky reef (below chart datum) See No. A-11g

11 Stranded wreck (any portion of hull above chart datum)

masts

12 Sunken wreck with only masts visible

14 Dangerous sunken wreck with less than 10 fathoms of water over it (See No. 6a)

wreckage

(14a) A number of sunken wrecks

21 Obstr

(14b) Obstruction of any kind

16 Sunken wreck, not dangerous to surface navigation or over which the depth exceeds 10 fathoms

foul

17 Foul ground

tide rips

18 Overfalls or tide rips

eddies

19 Eddies

20 Kelp, any kind

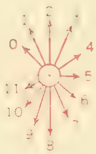
| | | |
|---|---|---|
| 21 | Bk. | bank |
| 22 | Shl. | shoal |
| 25 | | breakers (see No. A-12) |
| 27 | Obstr. | obstruction |
| 28 | Wk. | wreck |
| (28a) | Wks. | wreckage |
| 33 | cov. | covers |
| 34 | uncov. | uncovers |
| 35 | rep. | reported |
| (35a) | 9 reported | shoal reported |
| 41 | P. A. | position approximate |
| 42 | P. D. | position doubtful |
| 43 | E. D. | existence doubtful |
| 44 | Pos. | position |
| 45 | D. | doubtful |

FIGURE 189.—Symbols and abbreviations for nautical charts (part IX).

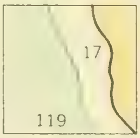
## P. Various Limits

| | | |
|---|---|---|
| 1 | | Leading line (Range line) |
| 4 | | Limit of sector |
| 5 | | Channel or course recommended |
| (5a) | | Alternate course |
| 7 | Cable area | Submarine cable |
| 8 | Pipe line<br>Pipe line area | Submarine pipe line |
| 9 | | Maritime limits in general |
| 10 | | Limit of fishing zone (fish trap areas bounded by orange lines) |
| 11 | | Limit of dumping ground (see Nos. P-9 & G-13) |
| 12 | | Anchorage limit |
| 13 | Airport | Limit of airport |
| 16 | | International boundary (also State boundary) |
| 18 | | Ice limits |
| (21) | Bdry. | Boundary |
| (22) | Bdry. Monu. | Boundary monument |
| (23) | | Reservation line |

## T. Tides and Currents

| | | |
|---|---|---|
| 1 | H W | high water |
| (1a) | H H W | higher high water |
| 2 | L W | low water |
| (2a) | L L W | lower low water |
| 3 | M T L | mean tide level |
| 4 | M S L | mean sea level |
| (8a) | M H W | mean high water |
| (8b) | M H H W | mean higher high water |
| (9a) | M L W | mean low water |
| (9b) | M L L W | mean lower low water |
| 17 | St. | stream |
| 18 | | current, general |
| 19 | 2 kn | flood stream |
| 20 | 2 kn | ebb stream |
| 23 | vel. | velocity |
| 24 | kn. | knots |
| (25) |  | Current Diagram |

## Q. Soundings

| | | |
|---|---|---|
| 2 | 27 | No bottom sounding |
| 5 | 30 FEET MAY 1939 | Dredged channels (controlling depth may be shown in separate note) |
| 9 |  | Swept areas (shown by green tint) (not yet covered by sufficient hydrographic surveys to show adequate soundings) |
| (16) | =6 5 | Stream |



## R. Depth Contours & Tints

| Feet | Fathoms |
|---|---|
| 0 | 0 |
| 6 | 1 |
| 12 | 2 |
| 18 | 3 |
| 24 | 4 |
| 30 | 5 |
| 36 | 6 |
| 60 | 10 |
| 120 | 20 |
| 180 | 30 |
| 240 | 40 |
| 300 | 50 |
| 600 | 100 |
| 1,200 | 200 |
| 1,800 | 300 |
| 2,400 | 400 |
| 3,000 | 500 |
| 6,000 | 1,000 |
| 12,000 | 2,000 |
| 18,000 | 3,000 |
| Or 10 fathoms and greater | |

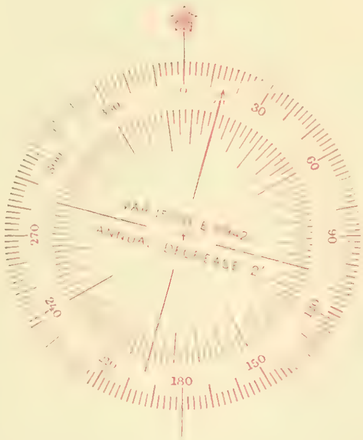
10
Or 100

FIGURE 189. — Symbols and abbreviations for nautical charts (part X).

# S. Quality of the Bottom

| | | |
|---|---|---|
| *1* | *Grd* | *ground* |
| 2 | *S* | *sand* |
| 3 | *M* | *mud* |
| 4 | *Oz* | *ooze* |
| 5 | *Ml* | *marl* |
| *6* | *Cl* | *clay* |
| 7 | *G* | *gravel* |
| 9 | *P* | *pebbles* |
| 10 | *St* | *stones* |
| *(10a)* | *Sp* | *specks* |
| *11* | *Rk* | *rock* |
| *(11a)* | *Bld (s)* | *boulder (s)* |
| 12 | *Ck* | *chalk* |
| 14 | *Co* | *coral* |
| *(14a)* | *Co Hd* | *coral head* |
| *(16a)* | *Vol Ash* | *volcanic ash* |
| *17* | *La* | *lava* |
| 18 | *Pm* | *pumice* |
| 21 | *Cn* | *cinders* |
| 23 | *Sh* | *shells* |
| *24* | *Oys* | *oysters* |
| *26* | *Spg* | *sponge* |
| *27* | *Grs* | *grass* |
| 33 | *Gl* | *globigerina* |
| 34 | *Di* | *diatom* |
| *39* | *fne* | *fine* |
| *40* | *crs* | *coarse* |
| *41* | *sft* | *soft* |
| *42* | *hrd* | *hard* |
| *43* | *stf* | *stiff* |
| *44* | *sml* | *small* |
| *45* | *lrg* | *large* |
| *46* | *stk* | *sticky* |
| *47* | *brk* | *broken* |
| *(47a)* | *rky* | *rocky* |
| *50* | *spk* | *speckled* |
| *51* | *gty* | *gritty* |
| *53* | *fly* | *flinty* |
| *54* | *glac* | *glacial* |
| *56* | *wh* | *white* |
| *57* | *bk* | *black* |
| *59* | *bu* | *blue* |
| 60 | *gn* | *green* |
| *61* | *yl* | *yellow* |
| 63 | *rd* | *red* |
| 64 | *br* | *brown* |
| 66 | *gy* | *gray* |
| 67 | *lt* | *light* |
| *68* | *dk* | *dark* |

# U. Compass



*The outer rose is in degrees with zero at true north. The inner rose is in points with the arrow at magnetic north.*

| | | |
|---|---|---|
| 1 | N. | *north* |
| 2 | E. | *east* |
| 3 | S. | *south* |
| 4 | W. | *west* |
| *5* | NE. | *northeast* |
| *6* | SE. | *southeast* |
| *7* | SW. | *southwest* |
| *8* | NW. | *northwest* |
| *21* | brg. | *bearing* |
| 23 | mag. | *magnetic* |
| *24* | var. | *variation* |
| *(27)* | deg. | *degrees* |
| *(28)* | dev. | *deviation* |

FIGURE 189. — Symbols and abbreviations for nautical charts (part XI).


FIGURE 190. — Section of finished nautical chart (slightly reduced).

# INDEX

*(The bold-face numbers in the left-hand column are the item numbers accompanying text headings. See preface for explanation of these numbers.)*

## A





465382—44——58

## C

| Page | Column | |
|---|---|---|
| 923 | 2 | 10th entry from bottom. For "When required" page no. is 796. |
| | | 9th entry from bottom. For "Seavalley" page no. is 55. |
| 925 | 2 | 8th entry. For Indentifyiny read Identifying. |
| | | Shoals, Prior surveys. Insert comma(,) after "surveys". |
| 926 | 1 | Simultaneous comparisons, Sounding Record. Change 2nd page no. from 762 to 760. |
| | | Simultaneous comparisons, Tabulations for season. Change page no. from 510 to 512. |
| | | Sinker for detaching rod. The two page nos. are 398 and 410. |
| 927 | 2 | 14th and 13th entries from bottom. Page nos. are interchanged. After 6545, correct page is 611; and after "fig. 136", correct page is 612. |
| 931 | 1 | Under "Speed, survey vessel", aline "scales, graphic" vertically under preceding entry. |
| 934 | 2 | Three-point fix(es). Transfer the ref. and page no. entries to the preceding entry, "Three-letter station names". |
| 935 | 1 | Last entry. For evel read level. |
| 936 | 1 | Tracing cloth distortion (table 23). Change ref. no. to 7114. |
| 937 | 1 | Trolley soundings. Change ref. no. to 3115b. |
| | 2 | 9th entry. Missing ref. and page nos. after "Plotting survey ship ---" are 3463 and 265, respectively. |
| 938 | 1 | 8th and 9th entries beginning with the words "Change" and "curves" should be vertically alined with "Bar-check" above. |
| | | 5th entry from bottom beginning "Abstract" should be vertically alined with the following entry, beginning "Observed". |
| 939 | 2 | Vincent hydrophone. Change the preceding page no. from 256 to 265. |

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IMPORTANT ERRATA

(Only errata in numbers and errata which might mislead the reader are included. Obvious typographical errors are omitted.)

| Page | Ref. | Par. | Line | |
|---|---|---|---|---|
| XIII | | | | Fig. 171. Change page no. 748 to 746. |
| 14 | | 7 | 3 | Change 1:180,000 or 1:20,000 to 1:80,000 or 1:120,000. |
| 73 | Fig.6 | | | Change 2nd and 3rd entries in "Remarks" column to 51° 32' 44."4 and 163° 06' 44."6, respectively. |
| 98 | | | | Last line on page. Insert comma(,) after "plotting". |
| 520 | 5551 | 2 | 1 | Last word in line is that. |
| | | | 2 | Last word in line is per. |
| 530 | | | 1 | First word on page is layer. |
| 539 | 562 | | 5 | Delete comma(,) after "between". |
| 645 | | | | Equation(1), complete parentheses around the quantity $(A - \theta)$. |
| 664 | 724 | | 1 | Last word in line. For know- read knows. |
| 763 | | | | Table 29. In second column, change 10 to 11 fathoms in four entries. |
| 780 | 8322 | 3 | 2 | For "a" read "the" before "Sounding Records". |

ERRATA IN INDEX

| Page | Column | |
|---|---|---|
| 891 | 1 | Beam compass, Use. 2nd page no. is 423. |
| 892 | 1 | Boat sheet(s), Offshore ——. Page no. is 207. |
| | 1 | Boat sheet use at Washington Office. 1st page no. is 204. |
| 895 | 1 | Under "Buoy(s), Survey", for Siganl read Signal. |
| 896 | 2 | Clock(s), hydrographic, Use. Correct ref. no. is 4542. |
| 897 | 1 | Collodon and Sturm. For Strum read Sturm. |
| | 2 | Under "Control", change 2nd ref. no. from 2213 to 2231. |
| 898 | 1 | 18th entry, "Classification of ---". Correct ref. no. is 2283. |
| 900 | 1 | 3rd entry. Change "on" to "of" in Abstract of control data. |
| | 1 | Change 9th entry from bottom to Penciling --- . . . . 7762 731. |
| 902 | 1 | In 13th entry, change key to keying. |
| | 2 | Under "motor, synchronous, Testing, etc.", correct ref. is 5267(j),(k). |
| 907 | 1 | Fishers Island Sound. For round read sound. |
| | 2 | 2nd entry from bottom. Change page no. from 51 to 53. |
| | 2 | Last entry. Correct ref. and page nos. are 166 and 51. |
| 908 | 1 | Geographic name(s), Migratory features. Change on to of. |
| | 1 | Graphs, temperature. Change "graphs" in parentheses to curves. |
| | 2 | High-water line. Change data in parentheses to details. |
| 909 | 2 | Hydrographic stations located with reference to. Delete remainder. |
| | 2 | 1st indented entry under above is detail on photographs. |
| 910 | 2 | Under "Hydrophone(s), Sono-radio buoy, Dorsey", interchange the page nos. opposite "cables" and "compared with". |
| 912 | 1 | Leadline(s) marked in fathoms or feet. For of read or. |
| | | Leadline(s), Marking for use in checking. Change Marking to Marks. |
| 913 | 1 | Log(s), ship, calibration. Change page no. from 35 to 351. |
| | 2 | Lyle gun. Change ref. no. from 263a to 2613a. |
| | | Under "Magnetic anomaly", indent "evidenced by, etc." 2 ens. |
| | | Under "Map(s)", aline "Local ---" vertically above "measure". |
| 914 | 2 | 15th entry under "Nautical chart(s)". Aline "Preparation" vertically above "Reporting". |
| 915 | 2 | Oscilloscope. Correct ref. no. is 5267(l). Letter "ell" in parentheses. |
| | | Last entry. Change page no. from 344 to 345. |
| 916 | 1 | Pelorus, Description. Change page no. from 345 to 344. |
| | 2 | Plotter, smooth-sheet. In last indented entry, change ref. no. from 7632 to 7624. |
| 921 | 1 | Receiving units, acoustic. In cross-reference add "Acoustic unit" after "also" and delete the words "and receiving". |
| 922 | 1 | 13th entry from bottom. Change page no. from 7901 to 790. |

(over)

| Page | Column | |
|---|---|---|
| 901 | 1 | 3rd entry from bottom. Add dash(——) at end of entry. |
| | 2 | Under "Dividers, spacing", capitalize Description. |
| 902 | 2 | Under "motor, starting", correct ref. is 5267(i). |
| 904 | 1 | 18th entry. For requeirements read requirements. |
| 905 | 2 | Under "Equipment and instrument(s)". 6th entry. Delete "s" from "Surveys". |
| 906 | 2 | Under "Field examinations", for Submittal read Submission. |
| 907 | 1 | Flagstaff, definition. Change hyphen(-) to comma(,). |
| | 2 | Under "Geographic names" for Consulation read Consultation. |
| 908 | 1 | Government services, etc. Ref. no. is 9135(B)(1). |
| | 2 | "Half-cosecants" and "Half-tangents" (table 41) in parentheses. |
| 910 | 1 | 4th entry. For linit read limit. |
| | | Under "Hydrographic survey records". Pluralize Requirements. |
| 911 | 1 | Under "Instruments", for invnetory read inventory. |
| | 2 | Interval between soundings. 1st cross-reference is Echo sounding frequency. |
| | | 5th entry under K. Begin investigated with a l.c. letter. |
| 912 | 1 | 10th entry from bottom. Begin standardization with a l.c. letter. |
| | 2 | 1st entry above "Leaks, etc.". Delete "s" from "Weights". |
| 914 | 1 | Memoranda, daily. For "for use n" read for use in. |
| 915 | 1 | Numbers. In 3rd indented entry aline "Position" vertically below "enunciated", and insert comma(,) after "hydrographic". |
| | | Office work. For progeess read progress. |
| | 2 | Under "Oscillator" insert heavy dash(——) after 312 Fathometer ——. |
| | | Paperweights. Insert comma(,) after Lead shot ——,. |
| 916 | 1 | Photogrammetry. Change "surveying" to surveys) inside parentheses. |
| | 2 | Under "Plane coordinate(s)", begin unadjusted with a l.c. letter. |
| 917 | 1 | Under "Plotting", delete the hyphen(-) from dead reckoning. |
| | 2 | Under "Progress sketches", capitalize Scale. |
| 918 | 2 | Under "Publications", add heavy dash(——) after C. & G. S. ——. |
| 919 | 1 | 5th entry. Delete the hyphen(-) from dead reckoning. |
| | | Under "R.A.R. distances". Insert comma(,) after "of" in 1st indented entry. |
| | | Under "R.A.R. equipment, ship". Capitalize Operation cycle. |
| | 2 | R.A.R. recorded in Bomb Record. For ot read not. |
| 920 | 2 | Last entry. For charonograph read chronograph. |
| 921 | 2 | Under "Reflection of sound in a homogeneous medium", capitalize Effect. |
| 922 | 1 | Registry numbers of surveys. For munbers read numbers. |
| | 2 | 4th entry. For propellor read propeller. |
| 923 | 1 | Under "Salinity determination", 11th entry is Records required. |
| 924 | 1 | Under "Sediments". Aline "Classification" vertically above "Descriptive". |
| | | Under "Sextant angles, Horizontal", aline "Measuring" below "Large". |
| 925 | 1 | 1st entry. Insert comma(,) after "navigating". |
| | 2 | Shoals, Isolated ——. Insert comma(,) after "surveying". |
| 926 | 2 | Smooth sheet, Drafting, etc. To the cross-reference add "and Lettering". |
| | | 8th entry from bottom. Delete the entry "paper (continued)". |
| 927 | 1 | Smooth sheet(s), R.A.R. Insert heavy dash(——) after R.A.R. |
| | | Under "Smooth sheet(s)", two consecutive entries are Verification of ——, report and Verification of ——, statistics. |
| | | 5th entry from bottom. Delete the parenthesis (() at beginning of line. |
| 929 | 1 | Sounding(s), Frequency of. Cross-reference is Echo sounding frequency. |
| | 2 | Sounding line jumps. Begin jumps with a l.c. letter. |
| | | 7th entry from bottom. Delete the entry "Sounding line(s)". |
| 930 | 1 | 6th entry from bottom. For nformation read information. |
| | 2 | Sounding Record(s), Reduction of soundings. Last part of cross-reference is Echo soundings, corrections to. |
| 931 | 1 | Last entry. Change page no. from 946 to 646. |
| | 2 | Stack, definition. Add C to ref. no. 8534C. |
| | | Star sight records, transmittal. Begin records with a l.c. letter. |
| 932 | 1 | 1st entry should read Station(s), control —— Continued. |
| | | Stylus, chronograph. In the cross-reference, delete the comma(,). |
| | 2 | Under "Sun sights", aline "Dead-reckoning" vertically below "Altitude". |
| 933 | 2 | 3rd entry. Capitalize Large ——. |
| 934 | 1 | Temperature(s), Seasonal. Capitalize all Seasonal entries. |
| 935 | 1 | Under "312 Fathometer tachometer", capitalize three entries beginning with Computation, Record, and Verification, respectively. |
| 936 | 2 | Traverse station(s). Delete (s) from Definition. |
| | | Triangle of error. For Tiangle read Triangle. |
| 936 | 2 | Under "Triangulation, Coastal". 1st entry, for shorline read shoreline. |
| 938 | 1 | 4th entry from bottom. Hyphenate divided word "Sounding". |
| | | Last entry. 4th word is of. |
| 940 | 1 | Wire-drag. Delete the 2nd entry of this, preceding "surveys". |
| | | Last entry. Delete the second hyphen(-) between "in" and "speed". |

M-2098-5(2)

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HYDROGRAPHIC MANUAL
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## MINOR ERRATA

(This list supplements the IMPORTANT ERRATA list. It contains all misspellings and other typographical errors discovered but not included in the other list; it omits instances of wrong fonts of type. Any errata discovered by the reader but not included on either list should be reported to the author.)

| Page | Ref. | Par. | Line | |
|---|---|---|---|---|
| 57 | | | 1 | 1st two words on page are in depths. |
| 71 | | | 5 | For traingulation read triangulation. |
| | 2214 | 2 | 5 | For theodolties read theodolites. |
| 89 | 232 | | 2 | For sucsequent read subsequent. |
| 118 | 2523 | 1 | 4 | For sohre read shore. |
| | | 2 | 4 | Transpose comma(,) at end of 4th line to end of 5th line. |
| 130 | 2545 | | 4 | Delete comma(,) after "cable". |
| 152 | | 1 | 6 | For white washed read whitewashed. |
| 161 | 276 | 4 | 7 | 1st two words are be thinner. |
| 176 | | | 1 | 1st three words are it is easier. |
| 211 | 326 | | 3 | For t me read time. |
| | | | 5 | For mai ed read mailed. |
| 253 | 3417 | | 4 | Delete 11th word given. |
| 336 | 4412 | 2 | 1 | For deadreckoning read dead reckoning. |
| | | 3 | 3 | Transpose comma(,) after "parallel" to after "parallel to". |
| 354 | 4462 | 6 | 2 | For on to read onto. |
| 494 | 5267(k) | 3 | 2 | Insert comma(,) in Then, if necessary,. |
| 515 | | | | Add period(.) at end of next to last line on page. |
| 527 | 56 | 2 | 3 | For 1st syllable "sles" read "less". |
| 531 | 5613 | | 2 | Insert comma(,) after "illustration". |
| 569 | | | | Last line on page. Insert "of" at beginning of line. |
| 612 | 655(c) | | 1 | 3rd word from end of line is leading. |
| 622 | 665 | 2 | 7 | Change is small to are small. |
| 630 | | | | Last line on page. Add period(.) at end of line. |
| 643 | | | | Pluralize center head to A. Graphic Methods. |
| 644 | 6826C | 1 | 1 | End of line reads at a center,. |
| | | 2 | 4 | Add hyphen(-) at end of line. |
| 657 | 7112 | | 2 | Change when to where. |
| 661 | 7131 | 2 | 2 | Add comma(,) at end of line after difficult. |
| 671 | | 6 | 2 | 2nd line of last 8-pt. paragraph. For joihing read joining. |
| 682 | | | | Line above center head. For ununeessary read unnecessary. |
| 693 | 752 | 2 | 2 | For dislcoses read discloses. |
| 716 | | | 2 | 1st word on line is integral. |
| 736 | 7824 | 4 | 5 | Insert comma(,) after the word protuberances. |
| 750 | | | | Change ref. no. in upper left-hand corner to 792. |
| 836 | | | | Tabulation of "Port Services". Delete semicolon(;) in Fuel oil. |
| 847 | | | | At end of last line on page, change period(.) to comma(,). |
| 869 | | | | Tide and Current Glossary is S.P. no. 228. |

## ERRATA IN INDEX

| Page | Column | |
|---|---|---|
| 890 | 1 | Arcs. Aline "Constructing" vertically above "Distance". |
| | 2 | Under "Astronomic line(s) of position", capitalize Combining ——. |
| | 2 | Attenuator circuit diagram. Delete comma(,). |
| 891 | 1 | Beacons. In 2nd indented entry, for Polot read Pilot. |
| | 2 | Under "Boat sheet(s)", capitalize "Circle" sheets. |
| 893 | 2 | Buoy(s). 1st indented entry is "anchors" l.c., delete comma(,) and dash(——). |
| 896 | 1 | Circle sheet construction. In 3rd indented entry pluralize centers. |
| | | Circle sheet construction. 6th entry. For fuctions read functions. |
| 897 | 2 | 4th entry from bottom. Insert comma(,) preceding "symbolization". |
| 898 | 1 | 3rd entry. Pluralize descriptions. |
| 899 | 1 | Under "Current(s)", insert comma(,) in Ocean ——, study of. |
| | | Insert comma(,) in "Cyclometer wheel, taut-wire apparatus, calibrating". |
| | 2 | 3rd entry from bottom. For Percise read Precise. |
| 900 | 1 | Depth(s) at crossings. Change "at" to a comma(,) inside parentheses(). |
| | | 8th entry from bottom. For Puprose read Purpose. |
| | 2 | 2nd entry, change "at" to a comma(,) inside parentheses(). |
| | | 3rd entry under "Descriptive Report(s)", delete "s" from "Aids". |
| 901 | 1 | Differences in depth. Change "at" to a comma(,) inside parentheses(). |

(over)

## D

## E

## H

## I

## J



## K



## L

## M

N

## O



## P

## Q



## R

## U



## V

## Y



## Z